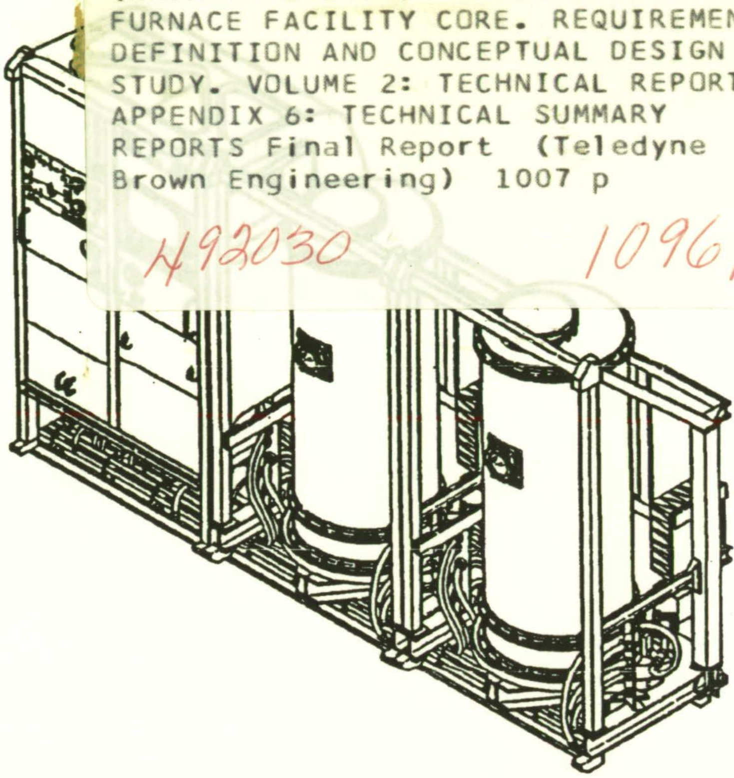
SPACE STATION FURNACE FACILITY CORE
Summary of Technical Reports



DR-2
May 1992

Volume II, Appendix 6 (Section 1)
Final Study Report (DR-8) of
Space Station Furnace Facility
Contract No. NAS8-38077

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SPACE STATION FURNACE FACILITY

REQUIREMENTS DEFINITION
AND
CONCEPTUAL DESIGN STUDY
FINAL REPORT
DR-8

Volume II - Technical Report
Appendix 6 Technical Summary Reports

Contract No. NAS8-38077
George C. Marshall Space Flight Center
Marshall Space Flight Center, Al 35812

May 1992
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ORIGINAL CONTAINS COLOR ILLUSTRATIONS

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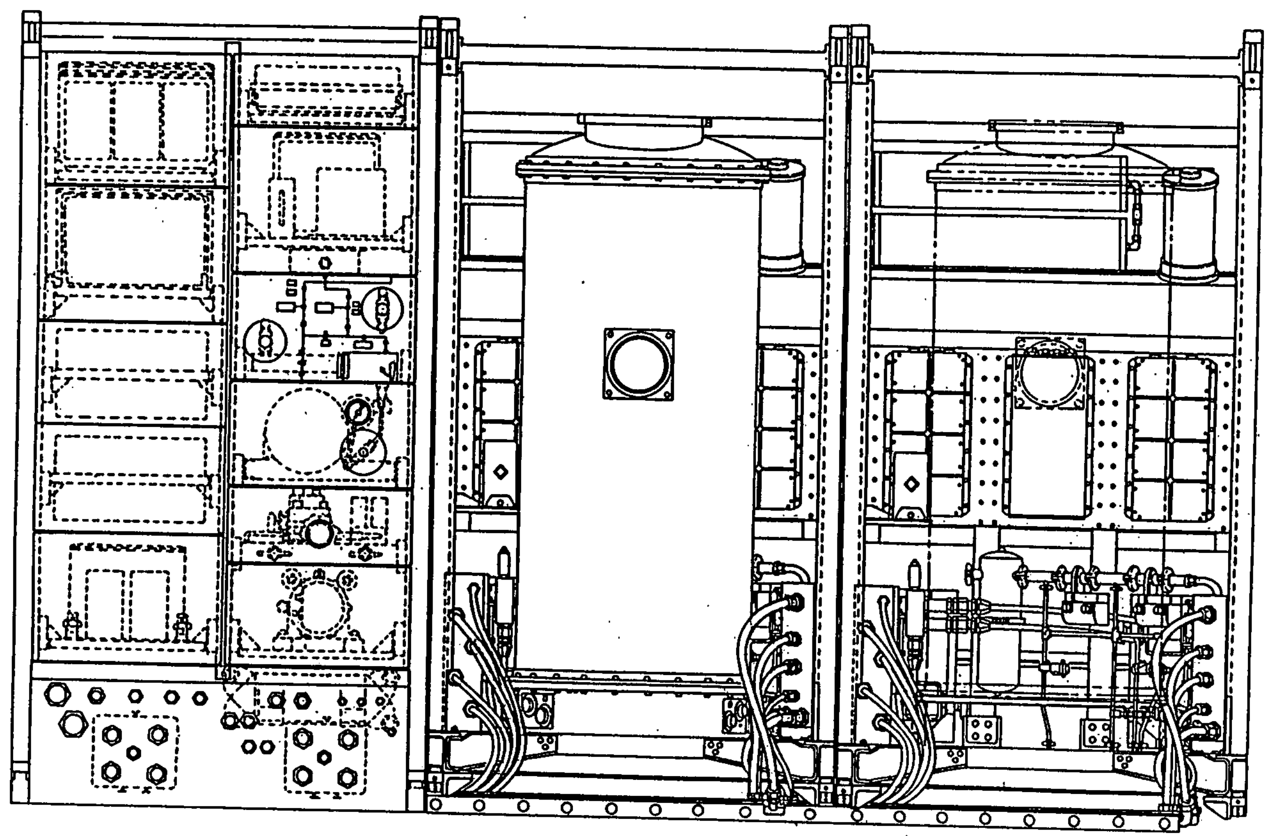


SSFF CONCEPT

INTRODUCTION

The Space Station Furnace Facility (SSFF) is a modular facility for materials research in the microgravity environment of the Space Station Freedom (SSF). The SSFF is designed for crystal growth and solidification research in the fields of electronic and photonic materials, metals and alloys, and glasses and ceramics, and will allow for experimental determination of the role of gravitational forces in the solidification process. The facility will provide a capability for basic scientific research and will evaluate the commercial viability of low-gravity processing of selected technologically important materials.

The facility is designed to support a complement of furnace modules as outlined in the Science Capabilities Requirements Document (SCRD). SSFF is a three rack facility that provides the functions, interfaces and equipment necessary for the processing of the furnaces and consists of two main parts: the SSFF Core Rack and the two Experiment Racks. The facility is designed to accommodate two experimenter-provided furnace modules housed within the two experiment racks, and is designed to operate these two furnace modules simultaneously. The SCRD specifies a wide range of furnace requirements and serves as the basis for the SSFF conceptual design. SSFF will support automated processing during the man-tended operations and is also designed for crew interface during the permanently manned configuration. The facility is modular in design and facilitates changes as required, so the SSFF is adept to modifications, maintenance, reconfiguration, and technology evolution.

The first SSFF launch is scheduled for late 1997. The Core Rack and Experiment Rack-1 will launch with Furnace Module-1 as the initial configuration for SSFF. This configuration of the SSFF is referred to as the Integrated Configuration 1 (IC1). IC1 will operate during the Man-tended phase of the SSF and the facility will be designed to operate in an automated state after the crew installs the payload and initiates the processing.

The second launch for SSFF is scheduled for 1999 with Furnace Module - 2 as the addition to the first payload. With the addition of the second furnace module, the SSFF will be in a fully operational mode, referred to as the Integrated Configuration-2 (IC2). IC2 will operate during the manned phase of the SSF program and therefore will utilize the crew to the extent practical.

The requirements for SSFF were taken from the SCRD which is dated January 24, 1992, and the design of the SSFF was derived based on those requirements. The furnace modules that are accommodated by the SSFF are listed below:

- High-Temperature-Gradient Directional Solidification Furnace Module (HGDSF)
- Low-Temperature-Gradient Directional Solidification Furnace Module (LGDSF)
- Vapor Crystal Growth Furnace Module (VCGF)

- Isothermal / Rapid Solidification Furnace Module (IRSF)
- Hot Wall Float Zone Module (HWFZ)
- Programmable Multizone Furnace Module (PMZF)
- Visibly Transparent Furnace Module (VTF)
- Interface / Radiographic Measurement (IRM)
- Thermophysical Property Measurement Furnace (TPMF)
- * Large Bore Low-Temperature-Gradient Directional Solidification Furnace Module (LBDSF)
- * High Pressure Furnace Module (HPF).

The furnaces listed with asterisks were considered for impact only since the furnace concepts are not currently developed in sufficient detail to be incorporated in the SSFF design.

From the furnace modules described above, NASA selected a strawman furnace complement for the SSFF design. The furnace modules that were considered to represent the widest range of resource requirements are listed below and their requirements are enveloped in the strawman complement consisting of two furnaces, Furnace Module-1 and Furnace Module-2:

- High-Temperature-Gradient Directional Solidification Furnace Module (HGDSF)
- Low-Temperature-Gradient Directional Solidification Furnace Module (LGDSF)
- Vapor Crystal Growth Furnace Module (VCGF)
- Programmable Multizone Furnace Module (PMZF)

From this strawman, resource requirements were reviewed for the SSFF system design. The following is a list of those resource requirements from which the SSFF is based: Furnace Module-1 is a module which is similar to the Crystal Growth Furnace (CGF) that is flying on USML-1 in 1992. Furnace Module 2 is the Programmable Multizone Furnace.

Resource Requirement	Furnace Module-1	Furnace Module-2
Nominal Heater Power	900 W	1200 W
Peak Power	2100 W	3000 W
Maximum Heat Up Rate	300 °C/hr	30 °C/hr
Maximum Temperature	1700 °C	1300 °C
Operating Atmosphere	Argon	Argon
Hard Vacuum Requirement	1 x 10^{-3} torr	Unknown
Coolant	Water	Water
Temperature Control Thermocouples	14	100
Sample Thermocouples	36	<10
Mass	327 kg	350 kg

In order to accommodate the furnace modules with the resources required to operate, SSFF developed a design that meets the needs of the wide range of furnaces that are planned for the SSFF. The system design is divided into subsystems which provide the functions of interfacing to the SSF services, conditioning and control for furnace module use, providing the controlled services to the furnace modules, and interfacing to and acquiring data from the furnace modules. The subsystems, described in detail in this document, are listed below with a general description provided:

- Power Conditioning and Distribution Subsystem (PCDS) - Provides the regulation, distribution and conversion of the SSF-provided power to the desired usable levels.

- Data Management Subsystem (DMS) - Provides process control, data acquisition, recording capabilities and interfaces for the crew and the SSF DMS for uplink, downlink and housekeeping functions.

- Software (SW) - Automates control of the SSFF hardware, handles internal and external interfaces, performs data acquisition, processing and storage.

- Gas Distribution Subsystem (GDS) - Supplies the backfill process gases for the furnaces and interfaces with the SSF Vent System to dispose of furnace waste gases.

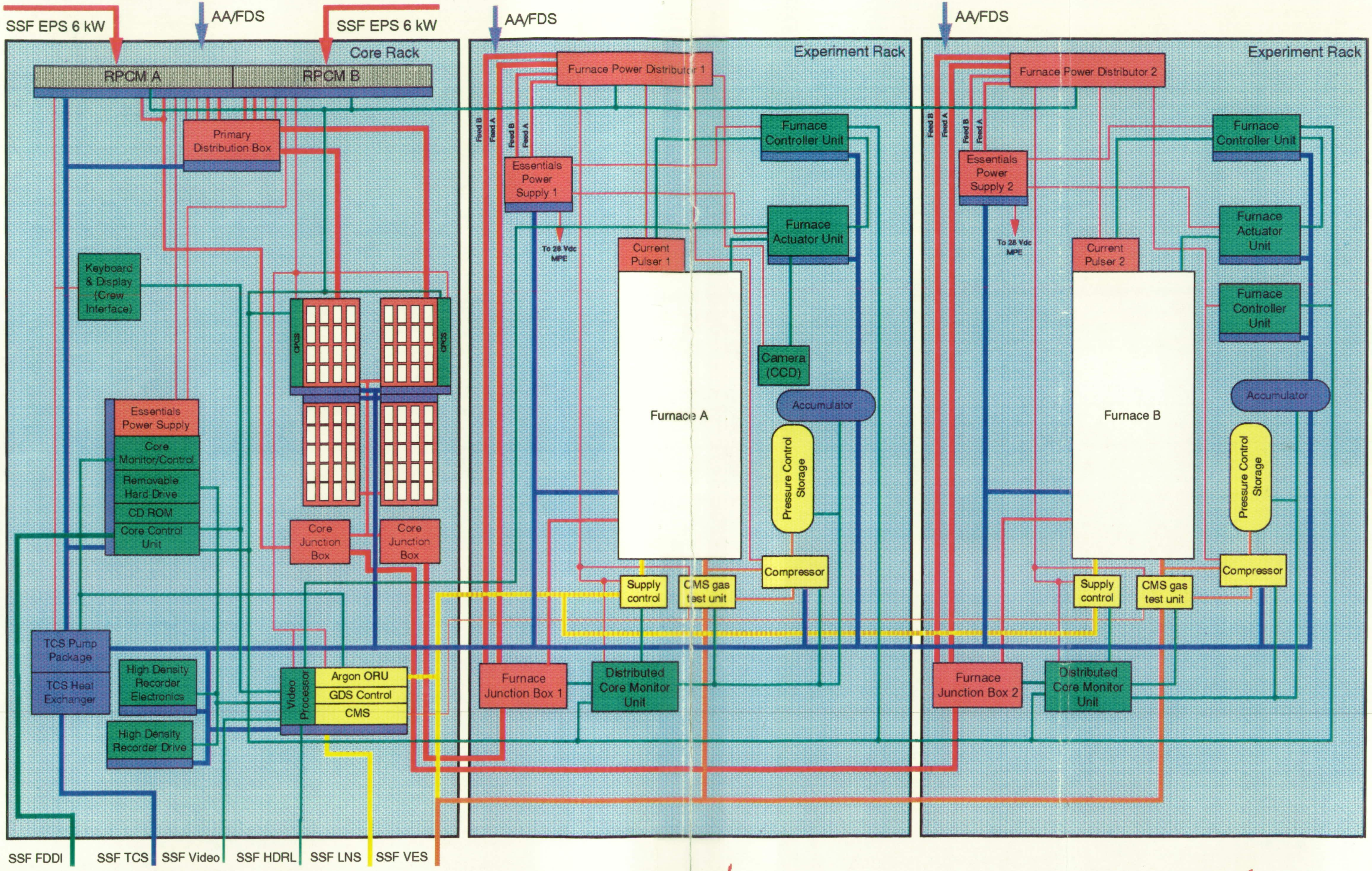
- Thermal Control Subsystem (TCS) - Interfaces with SSF TCS and provides heat rejection for all SSFF components.

- Mechanical Structures Subsystem (MSS) - Provides structural interface for the SSFF subsystems and the furnace modules and serves as the physical interface to SSF.

Two sets of interfaces exist for the SSFF while in orbit; Space Station Freedom (SSF) and the furnace modules. The SSFF is designed so that the Core Rack serves as the central interface for the Furnace Modules to the SSF. Resources from the SSF are supplied to the Core Rack and those resources are routed from the Core Rack to each of the Experiment Racks. The Experiment Racks serve as the Furnace Module interface to the Core and do not receive services directly from SSF except Fire Detection and Suppression (FDS), which is a resource that every powered rack receives. The services obtained from the Core rack to the Experiment Racks are considered optional and are driven by the requirements of the Furnace Module located in that rack. The subsystems required to accommodate these furnace requirements are shown in the block diagram on the following page, and are designed to meet the requirements of the SSF and the Science Capabilities Requirements Document. Each subsystem is shown in a different color as listed below:

Power Conditioning and Distribution Subsystem	RED
Data Management Subsystem	GREEN
Gas Distribution Subsystem	YELLOW
Thermal Control Subsystem	BLUE

The following reports describe in detail the subsystems that comprise the SSFF. These reports include description of the requirements, ground rules and assumptions, concept design, description of individual components, sketches, interface diagrams, and resource requirements for each subsystem. The specifications for operation of each subsystem are contained in the Contract End Item Specification, 320SPC0001.



FOLDOUT FRAME 1

FOLDOUT FRAME 2

320RPT0008

SPACE STATION FURNACE FACILITY POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM (SSFF PCDS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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320RPT0008

SPACE STATION FURNACE FACILITY POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM (SSFF PCDS) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

Prepared By :

Advanced Programs Department
Space Programs Division
Teledyne Brown Engineering
Huntsville, AL 35807

EXECUTIVE SUMMARY

This report describes the requirements, assumptions, and analysis used to baseline the concept for the Space Station Furnace Facility Power Conditioning and Distribution Subsystem (SSFF PCDS). Through the evaluation of these parameters a subsystem was designed which would fulfill the requirements set forth for the SSFF PCDS in the Science Capabilities Requirements Document (SCRD) and other applicable documents. This report presents, in detail, each component of the baseline concept, a description of each components function, subsystem resource requirements, and subsystem interfaces.

After evaluating the requirements for the PCDS, an evaluation of different PCDS concepts was conducted to determine which concept would best meet the requirements of the SSFF. These concepts, distributed, centralized, and hybrid, were each capable of meeting the needs of the SSFF somewhat; however, it was determined that the hybrid concept best met the overall goals of the SSFF when measured against the stated criteria.

The baseline concept provides for SSFF power to be brought into the facility at the core rack, to be distributed to core rack equipment, to be distributed to experiment rack equipment, and to be distributed to the furnace modules all from the centralized core. Secondary distribution within each experiment rack allows for growth of the PCDS power capabilities by providing a point at which power can also be brought into the SSFF through the experiment rack at some future time. Power distribution will be controlled by the SSFF Data Management Subsystem (DMS).

All power conditioning will be accomplished in the core rack prior to any distribution to the experiment racks. Conditioning for furnace heaters will be accomplished by banks of variable voltage output, 120 volt, current limited, DC-DC power converters or modules. These power modules will be available for individual driving of heater elements and will also have the flexibility to be combined in series to drive high power heaters. This "stacking" of power modules will be done in the core junction boxes, which will be reconfigured or replaced with each new furnace complement. This conditioning, coupled with the reconfigurable core junction boxes, will provide PCDS flexibility and will allow the SSFF to accommodate various types of furnaces. Furnace heaters will interface with the PCDS at the furnace junction boxes.

In addition to baselining the PCDS conceptual design, this report uses candidate components to estimate required subsystem resources. The estimated total nominal power draw of the current SSFF concept is 6 kW with usage peaking at 8.4 kW. Of this peak demand, 2.7 kW is allocated to PCDS components and 3.9 kW is allocated to the total heater power of the two furnaces operating in a nominal situation. It is assumed that 100% of the PCDS inefficiency power will be rejected to the SSFF Thermal Control System (TCS). The total PCDS components mass is estimated at 264 kg occupying volumes in the core and experiment racks of 0.23 m^3 and 0.12 m^3 respectively.

Two major concerns facing the PCDS baseline concept are:

1. The requirement to provide current pulsing to each experiment rack.
2. The impact of the Space Station Freedom (SSF) Electrical Power System (EPS) on SSFF essential power for safing.

In order to meet the current pulsing requirements stated in the SCRD, a detailed study and conceptual design process will have to be undertaken. The results of this study will determine the impact on the PCDS, which in all likelihood will invoke major impacts to power demand, current draw, distribution equipment and wire sizes.

SSFF power demands project the need to be located in a 12 kW SSF rack. A payload located in a 12 kW rack must receive power from two 6 kW buses for demand and electrically tie the two together to provide essential safing power. The electrical tying of buses together poses two major problems for the PCDS.

- SSF requires that 1 MΩ of electrical isolation be maintained between buses. This requirement significantly impacts the PCDS design, but is addressed by the current PCDS baseline concept.
- Since during nominal operations the SSFF power demand is estimated to peak above 6 kW, both 6 kW feeds will be utilized. SSF requires that a back up feed be available to racks for safing and it is likely that SSFF will be required to initiate safe shutdown if either bus is lost. This impact could severely limit SSFF operations.

The studies listed above and other required trades and analyses detailed in this report are outlined in Appendix A.

ABBREVIATIONS AND ACRONYMS

CCU	Core Control Unit
CGF	Crystal Growth Furnace
CJB	Core Junction Box
cm	centimeter
CPC	Core Power Conditioner
CPD	Core Power Distributor
DMS	Data Management Subsystem
EPS	Electrical Power System
ESS	Essentials
FJB	Furnace Junction Box
FPD	Furnace Power Distributor
FPE	Furnace Peculiar Equipment
GDS	Gaseous Distribution Subsystem
kg	kilogram
kW	kilowatt
m	meter
lb	pound
MCU	Monitor and Control Unit
PCDS	Power Conditioning and Distribution Subsystem
PMZF	Programmable Multi Zone Furnace
RPCM	Remote Power Controller Module
RPDA	Remote Power Distribution Assembly
SSF	Space Station Freedom
SSFF	Space Station Freedom Facility
TCS	Thermal Control Subsystem
VDC	Volts Direct Current

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The Space Station Furnace Facility (SSFF) will be a modular facility for materials research in the microgravity environment of the Space Station Freedom (SSF). The SSFF will accommodate two experiment racks which will be operated, regulated, and supported by a core of common subsystems. The SSFF will consist of two experiment racks and the SSFF core rack, which houses the subsystems required to provide the support functions for the accommodated furnaces.

The SSFF Power Conditioning and Distribution Subsystem (PCDS) is composed of the equipment necessary to condition, and distribute power provided by the SSF Electrical Power System (EPS) to SSFF subsystems. The scope and purpose of this report is to present the SSFF PCDS requirements and the design concept developed to meet these requirements. The report includes a description of the requirements, an overall PCDS concept, and descriptions of the individual PCDS components.

The bulk of the power to be distributed by the PCDS will be consumed by the furnace heaters with the remainder serving as housekeeping power to the SSFF subsystems. The PCDS will employ power converters to condition SSF provided power to a level useable by SSFF subsystems and furnaces. Distribution boxes will employ Remote Power Controllers (RPCs) to switch loads and to excite actuators. Junction boxes will provide connection points between wiring harnesses which will route power to furnace heaters and will provide flexibility to re-route power dependent on furnace requirements. PCDS monitoring and control will be provided by the SSFF Data Management Subsystem (DMS). Thermal control will be maintained by the SSFF Thermal Control Subsystem (TCS).

1.2 GROUNDRULES AND ASSUMPTIONS

The following assumptions are made with regard to furnace operations:

- The two accommodated furnaces will never peak simultaneously. While one furnace is peaking, the other furnace will be in a normal operation mode or dormant.
- Based upon the furnace requirements of CGF and PMZF, and having considered all candidate furnaces as stated in the SCRD, the SSFF will consume its maximum power draw when PMZF is peaking at 3000 W and CGF is operating normally at 900 W.
- PMZF will have 32 zones (in reality this number may be less).
- It is assumed that the two experiment racks will be located to one side of the core rack and that the core rack will be a 12 kW location.
- It is assumed that both SSF EPS 6 kW power feeds will never be lost simultaneously. At least one feed will always provide at least enough power for the safe shutdown of the SSFF.

2. REQUIREMENTS

2.1 GENERAL

The SSFF PCDS shall meet the requirements identified in documents DR-7, Contract End Item Specification(CEI) for SSFF and the requirements stated or implied by the Science Capabilities Requirements Document(SCRD). The PCDS will be responsible for distributing and conditioning up to 12 kW of electrical power to SSFF subsystems and accommodated furnaces.

2.2 INTERFACE REQUIREMENTS

The SSFF PCDS will interface directly with the SSF, as well as with the SSFF subsystems and furnace modules. The PCDS interfaces are illustrated in Figure 2-1. Arrows indicate the direction of flow. A description of these interfaces is given below.

2.2.1 SSFF PCDS with SSF

The SSFF PCDS will interface with the SSF by connecting to two 120 VDC power buses. Each bus will have the capability to deliver 6 kW to the SSFF core rack and 6 kW to each experiment rack. Since 3 kW and 6 kW SSF payload racks use one bus as a primary feed and the other as an essential feed, 12 kW racks are required to maintain 1 MΩ of electrical isolation between the two buses at all times (SSF Electric Power Specifications and Standards SSP 30482). No true essentials bus exists at this time, only the two main buses. This means that a 12 kW rack must tie the two buses together whenever essentials power will be required.

The two SSFF power Buses (Bus A & Bus B) will feed the PCDS via SSF provided Remote Power Distribution Assemblies (RPDAs) or through a SSFF designed assembly (similar in function).

Each RPDA provides a physical connection point for a bus and a mounting backplane for a Remote Power Controller Module (RPCM). The RPCM is a group of fast-response, solid-state circuit breakers or Remote Power Controllers(RPCs). The RPCM is controlled via a local MIL-STD-1553 serial data bus by the SSFF DMS. Each switch is assigned a normally open or closed position and will assume this position once the RPCM has been energized and each switch has performed a self check.

RPDAs are available in either a one or two position configuration which will accommodate either 1 or 2 RPCMs respectively. RPCMs are available in five different types:

- Type I - provides eight switches rated at 12 Amps each.
- Type II - provides four switches rated at 25 Amps each.
- Type III - provides two switches rated at 50 Amps each.
- Type IV - provides a single switch 65 Amp device.
- Type V - type V is knows as a hybrid RPCM, it provides sixteen 3.5 Amp switches and two 12 Amp switches.

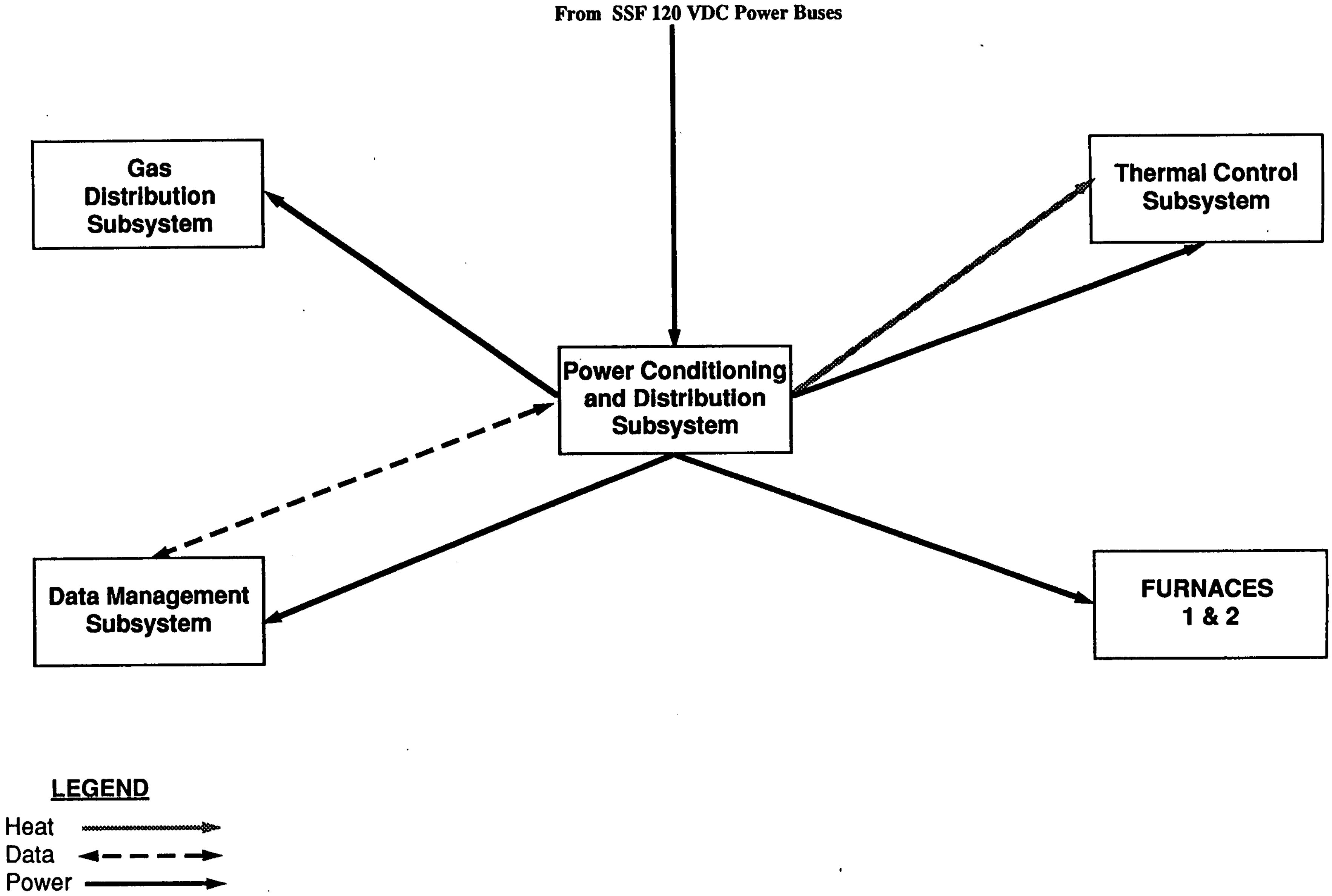


FIGURE 2-1. PCDS SSFF SUBSYSTEM INTERFACES

SSF provided RPDAs and RPCM are illustrated in Section 3.2.2, Figures 3-5 and 3-6 respectively.

2.2.1.1 Space Station Power Allocation - PUMA Document No. TD-001-2.C.2.2 Section 2.1 provides SSF power allocation estimates. At MB01 (Nov-95) the total station capability will be 18.75 kW average power, at MB10 (Dec-97) the total station capability will be 37.5 kW average power, at PMC (Permanent Manned Capability) the total station capability will be 56.25 kW average power, and at EMCC (Eight Man Crew Capability) the total station capability will be 75 kW average power.

SSFF launch is scheduled for late 97 at which time the available power to payloads will be 33.5 kW. This number decreases as loads are added, dipping to 25 kW in Sep 98 before jumping to 46.5 kW in Dec 98.

Memorandums of Understanding (MOU's) have been agreed upon by NASA and the international users of SSF. These MOU's establish payload power allocations. The MOU's presently define the U.S. Lab allocation as 48.5% of payload available power. At MB-17 (PMC) this equates to a total of 13.74 kW available for U.S. Lab use. For design purposes, SSFF PCDS will assume 13 kW available to USL, recognizing that this 13 kW must be shared with other USL racks.

2.2.2 SSFF PCDS With Furnace Modules

The SSFF must accommodate any two of the seven furnaces identified in the SCRD. Since two of the listed furnaces represent the most extreme requirements for power, these two have been chosen to serve as strawman furnaces. The requirements of these strawman furnaces will serve as design drivers for the SSFF PCDS design. These furnaces are the Crystal Growth Furnace (CGF) and the Programmable Multi-Zone Furnace (PMZF). CGF is a working furnace developed by Teledyne Brown Engineering (which will fly on USML-1) with operational data available. The PMZF is being developed by Lewis Research Center. Preliminary conceptual design information provided by Lewis is presented in this document. The PCDS design must have the capability to accommodate these two furnaces while remaining flexible enough to accommodate other variations of furnace complements. The current furnace requirements for CGF and PMZF applicable to PCDS are listed in Table 2-1.

The furnace modules will be the largest single users of power within the SSFF. Each furnace module will be supplied power based on furnace requirements and typical furnace timelines. Each furnace module will be powered, monitored, and controlled independently to follow a temperature profile provided and controlled by software. The furnace power requirements will be met by a collection of power converters or modules. These power modules will be

TABLE 2-1. STRAWMAN FURNACE REQUIREMENTS

	CGF[1]	PMZF[2]
Peak Furnace Power Required	2100 W	3000 W
Nominal Furnace Power Required	900 W	1200 W
Maximum Total Heater Currents	140 A	320 A
Maximum Individual Heater Current	20 A	10 A
Maximum individual heater Voltage	60 VDC	28 VDC
Maximum Individual Heater Power	900 W	TBD
Heater Resistance Range	0.5 to 3.0 Ω	2 to 3 Ω
Number of Heaters	7	32

1 Based upon SP-RPT-6752A, JA-55-036A p. 24

2 Based upon information supplied by Lewis Research Center.

configurable to accommodate various furnaces and/or furnace configurations. They will also be able to provide outputs of controllable power based on heater power and/or heater temperature.

2.2.3 SSFF PCDS with Core Subsystems

The PCDS will be required to supply power to furnace modules and SSFF subsystems: Data Management Subsystem (DMS), Gas Distribution Subsystem (GDS), and Thermal Control Subsystem (TCS).

Total SSFF power demand is the sum of furnace required power, SSFF subsystems demand, and the power required to overcome equipment inefficiencies. A breakdown of these requirements is shown in Table 2-2. The power is tabulated in three different manners: Connected Load, Nominal Power Draw, and Power Draw at Facility Peak.

Connected Load is the summation of the maximum power ratings of all SSFF equipment with no regard to duty cycle. This number is shown in an effort to demonstrate the amount of connected load to the system, and is an inaccurate way to calculate SSFF demand since all SSFF equipment will never be energized simultaneously.

Nominal power draw is a summation of all SSFF power drawing equipment when the facility is operating in a normal mode. This number considers duty cycles of equipment and normal equipment status during operation. This total is provided to demonstrate the SSFF's total electrical power draw during normal operations (2 furnaces running simultaneously at nominal power), and represents the most accurate estimate of SSFF's normal power consumption.

TABLE 2-2. SSFF POWER DEMAND (watts)

Power Consuming Equipment (Qty.)	Connected Load	Nominal Power Draw	Power Draw at Facility Peak
Furnaces			
CGF	2800	900	900
PMZF	3200	1200	3000
DMS			
Centralized Equipment			
Core Control Unit	155.0	155.0	155.0
Removable Hard Drive	84.0	84.0	84.0
CDROM /WORM Drive	70.0	70.0	70.0
High Density Recorder	204.0	204.0	204.0
Video Processor Unit	145.0	145.0	145.0
Core Monitor/Control Unit	43.0	43.0	43.0
Crew Interface	60.0	60.0	60.0
CPC Stimulus(2)	88.0	88.0	88.0
Distributed Equipment			
Furnace Control Unit(3)	309.0	309.0	309.0
Furnace Actuator Unit(2)	240.0	240.0	240.0
DCMU(2)	96.0	96.0	96.0
GDS			
Centralized Equipment			
Latching Solenoid Valve (4)	144.0	7.2	7.2
Position Sensor (Man Valve)	2.0	2.0	2.0
Pressure Transducer(3)	3.0	3.0	3.0
Contamination Monitor	150.0	150.0	150.0
Distributed Equipment			
Latching Solenoid Valve(12)	432.0	21.6	21.6
Compressor(2)	400.0	20.0	20.0
CM Sensors(4)	20.0	1.0	1.0
Pressure Transducer(6)	12.0	12.0	12.0
PCDS			
Centralized Equipment			
RPCM(2)	37.4	37.4	37.4
Primary Distribution Box	73.9	73.9	73.9
Core Power Conditioner	2000.0	700.0	1300.0
Essentials Power Supply	205.3	205.3	205.3
Voltage/Current Sensor(4)	4.0	4.0	4.0
Line & Connector Loss[1]	335.8	258.8	290.4
Distributed Equipment			
Furnace Power Distributor(2)	37.4	37.4	37.4
Essentials Power Supply(2)	180.7	180.7	180.7
Current Pulser(2)	80.0	80.0	80.0
Voltage/Current Sensor(132)	132.0	132.0	132.0
Line & Connector Loss[1]	392.7	348.7	348.7

TABLE 2-2. SSFF POWER DEMAND (watts) (Continued)

Power Consuming Equipment (Qty.)	Connected Load	Nominal Power Draw	Power Draw at Facility Peak
TCS			
Centralized Equipment			
Pump Package	132.0	132.0	132.0
Flow Meter(2)	3.0	3.0	3.0
Flow Control Valve(2)	14.0	0.7	0.7
Temperature Sensor(5)	0.6	0.6	0.6
Pressure Transducer(3)	3.5	3.5	3.5
Shutoff Valve(2)	14.0	0.7	0.7
Distributed Equipment			
Temperature Sensor(6)	0.7	0.7	0.7
Pressure Transducer(2)	2.3	2.3	2.3
Flow Meter(2)	3.0	3.0	3.0
Flow Control Valve(2)	14.0	0.7	0.7
Shutoff valve(2)	14.0	0.7	0.7
TOTALS	**12,337.3**	**6,016.9**	**8,448.5**

Efficiencies are based on vendor supplied data are typical. These efficiencies will vary over the operating range.
1 Based on 10% loss of consumed furnace power and 5% loss of SSFF housekeeping power

Power draw at Facility peak is a summation of SSFF power drawing equipment in a mode which will cause SSFF total power demand to be at a maximum. It is assumed that CGF and PMZF power will never peak simultaneously; therefore, this situation exists when CGF is operating normally at 900W and PMZF is operating at a peak of 3000W. SSFF subsystems are assumed to be operating nominally during this peak.

These demands are based on information provided by SSFF subsystem leads and vendor supplied data. PCDS power estimates are based on the current PCDS design and the candidate components described in section 3.2 and Appendix C. These estimates are typical and will evolve as the SSFF system design solidifies.

Figure 2-2 summarizes the PCDS to SSF and PCDS to SSFF interfaces.

2.2.4 Crew

SSF crew will be utilized in the installation, reconfiguration, furnace module changeout, and maintenance relating to the SSFF PCDS.

2.2.5 GSE

GSE requirements for the SSFF are TBD.

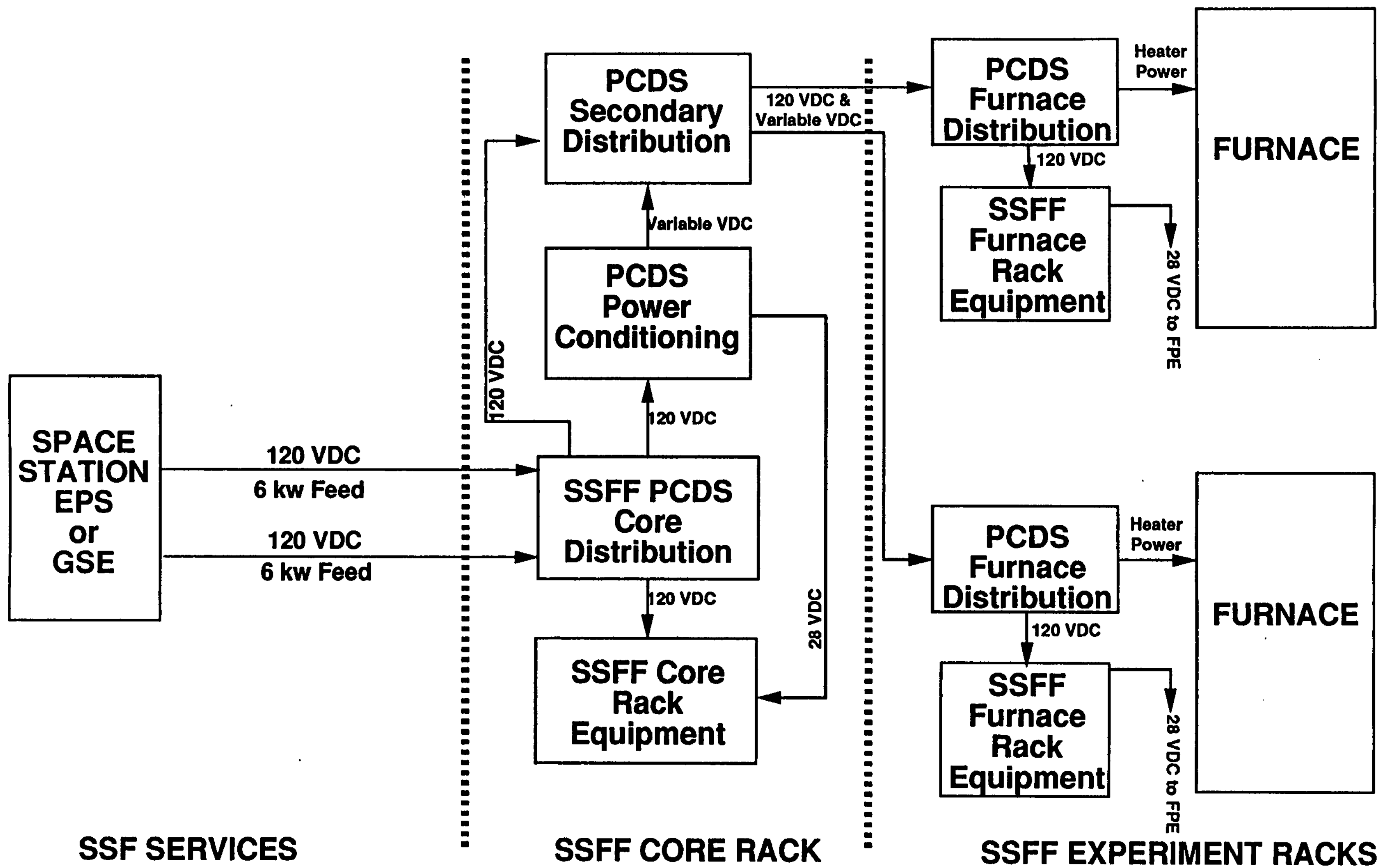


FIGURE 2-2. PCDS INTERFACES

3. CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

To meet the requirements set forth for the SSFF PCDS, three different PCDS concepts were considered: 1) Centralized, 2) Distributed, and 3) Hybrid. Each concept was analyzed and evaluated with regard to the goals of the SSFF. The criteria used to evaluate each concept are as follows:

- Complexity
- Efficiency
- Evolutionary Growth Potential
- Human Factors
- Mass
- Orbital Replacement Units
- Rack Fold Down
- Reconfigurability
- Reliability
- Subsystem Impacts
- Safety
- Volume

After consideration of each concept with regard to the criteria, a baseline concept was selected. A description of each of the concepts with regard to the selected criteria follows.

3.1.1 Centralized Concept

The centralized concept involves interfacing with the SSF EPS in each of the three racks, routing the power to a centralized point in the core rack, and distributing the power to SSFF subsystems and furnaces. It is illustrated in Figure 3-1. Power from each of the three racks would be routed to a central location in the core rack called the Primary Power Distributor. The distributor would either send the power on to Power Conversion modules which would convert the power to a usable form for use by components in the facility or send it directly to the experiment racks as 120 VDC for use by specialized components. The Power Conversion modules then send the power to a Secondary Power Distribution Assembly responsible for carrying the power to the experiment racks and to the furnace heaters.

The centralized concept results in a complex PCDS core rack design and a simple PCDS experiment rack design. Since all conditioning and primary distribution is performed in the core rack, the experiment rack serves only as a interface location for EPS to the PCDS and the furnace to the PCDS. This results in a large number of interrack cables since, in addition to the cabling

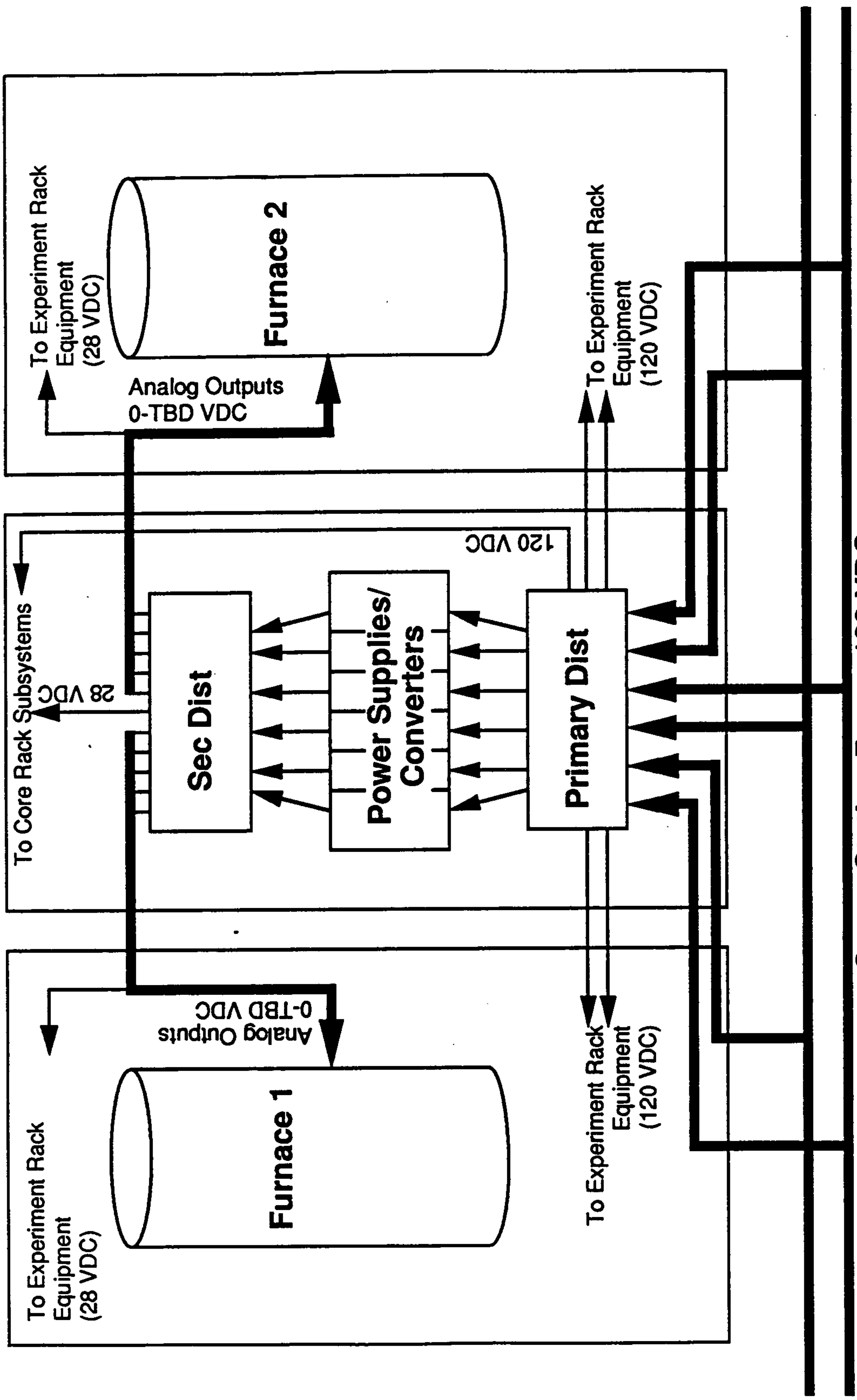


FIGURE 3-1. CENTRALIZED PCDS CONCEPT

routing EPS power to the core, each load requires its own dedicated power line from the core distribution. This cabling between racks will impact efficiency. Any high current drawing components, such as the current pulsing equipment, located in the experiment rack will have to overcome a large amount of line losses due to the length traversed between the core and the experiment rack.

Furnace developers designing furnaces which would increase the total SSFF power demand above 12 kW could be accommodated by the centralized PCDS. SSFF capability would approach 24 kW (12 kW at core rack, 6 kW at each experiment rack). This power could be routed to either of the furnace modules as required.

Crew maintenance of the experiment rack would be simplified by the centralized concept. Since no PCDS components, besides interface points, reside in the experiment rack, little distributed component maintenance would be required. PCDS Components would be accessible for repair without requiring the crew to relocate test equipment, tools, and procedures during the maintenance operations. Maintenance of the core rack requiring rack fold down, however, would be affected. Changeout and fold down of the racks would be very difficult with the centralized concept due to the large number of interrack cabling required between the core and the furnaces. Interrack studies performed by Teledyne Brown indicate that the number of cables that can be routed between racks, while meeting SSF rack fold down requirements, is limited.

The centralized PCDS would make efficient use of mass. Total system mass would be held to a minimum since secondary distribution boxes in the experiment rack are not utilized. One secondary distribution box would direct power to both experiment racks and to core SSFF subsystem equipment.

All PCDS Orbital Replacement Units, excluding cable harnesses, would be contained within the core rack. As mentioned above, secondary distribution could be performed by one assembly rather than multiple ones. This would reduce the number of ORU changeouts required when maintaining secondary distribution problems. Although the number of ORUs would be reduced, the size and complexity would increase thus reducing the reliability of the ORUs and increasing the probability of failure. Trouble-shooting failures would be simplified in a centralized scheme since specific functions can be traced to individual boxes residing in the core rack. ORU changeout would be impacted by the difficulty of rack fold down mentioned above.

Perhaps the greatest advantage of the centralized concept is the reconfigurability offered by locating power conditioning in a centralized core. In the centralized scheme, conditioned power from the core rack may be divided and routed to furnaces as their requirements deem necessary. Theoretically, all conditioned power could be routed to a single experiment rack to drive a high power furnace. In a distributed scheme, each furnace is power-limited by the capability of the

conditioner residing in its rack(barring an elaborate jumper scheme to route one experiment racks conditioned power to the other).

Under a centralized scheme, other SSFF subsystems are limited in the number of components which could be located in the experiment rack. This restriction is attributable to limits on the number of cables which can be routed between racks. TCS cold plate requirements and DMS control requirements for the centralized PCDS would be reduced due to the integration of functions into centralized assemblies. DMS would not be required to provide distributed intelligence in the experiment rack for PCDS control, thus allowing DMS to centralize as well, and reduce software complexity.

No safety related impacts are foreseen to be associated with the centralized PCDS other than those normally associated with electrical power systems.

Total utilized facility volume would be reduced by a centralized PCDS due to the collapsing of equipment functions into volume efficient assemblies. Experiment rack volume would be freed allowing subsystem components in the rack as well as furnace peculiar equipment (FPE). Core rack utilized volume would be increased due to the location of PCDS components in the core. This could result in an impact on SSFF core subsystems.

3.1.2 Distributed Concept

The distributed concept takes a different approach to providing power to the racks of SSFF and is illustrated in Figure 3-2. Power to each of the SSFF rack locations would enter and be distributed within the rack where it is used. No interrack power distribution circuitry would exist. In this configuration, interrack connections would be required only for control and data lines. Each of the racks would have its own distribution equipment to provide power to the various components in the rack. All necessary conversion of power would be accomplished in the rack where the power is consumed.

The distributed concept results in a complex system with the complexity of the system evident in the experiment racks as well as the core. Distributors are located in each of the three SSFF racks. Each distributor feeds the loads in its dedicated rack only. Each distributor requires control, increasing DMS complexity. Interrack cabling is reduced substantially, since only control and data lines will be routed between racks.

Efficiency of the distributed system should be much increased over that of the centralized. Since power is consumed in the rack where it enters the system, losses from power transmission should be minimal.

Furnace developers designing furnaces which would increase the total SSFF power demand above 12 kW could be accommodated by the distributed PCDS without major modifications to the system. Theoretically, SSFF capability would approach 24 kW(12 kW at core rack, 6 kW at each experiment rack). This added capability is misleading, however, since each rack is limited by the

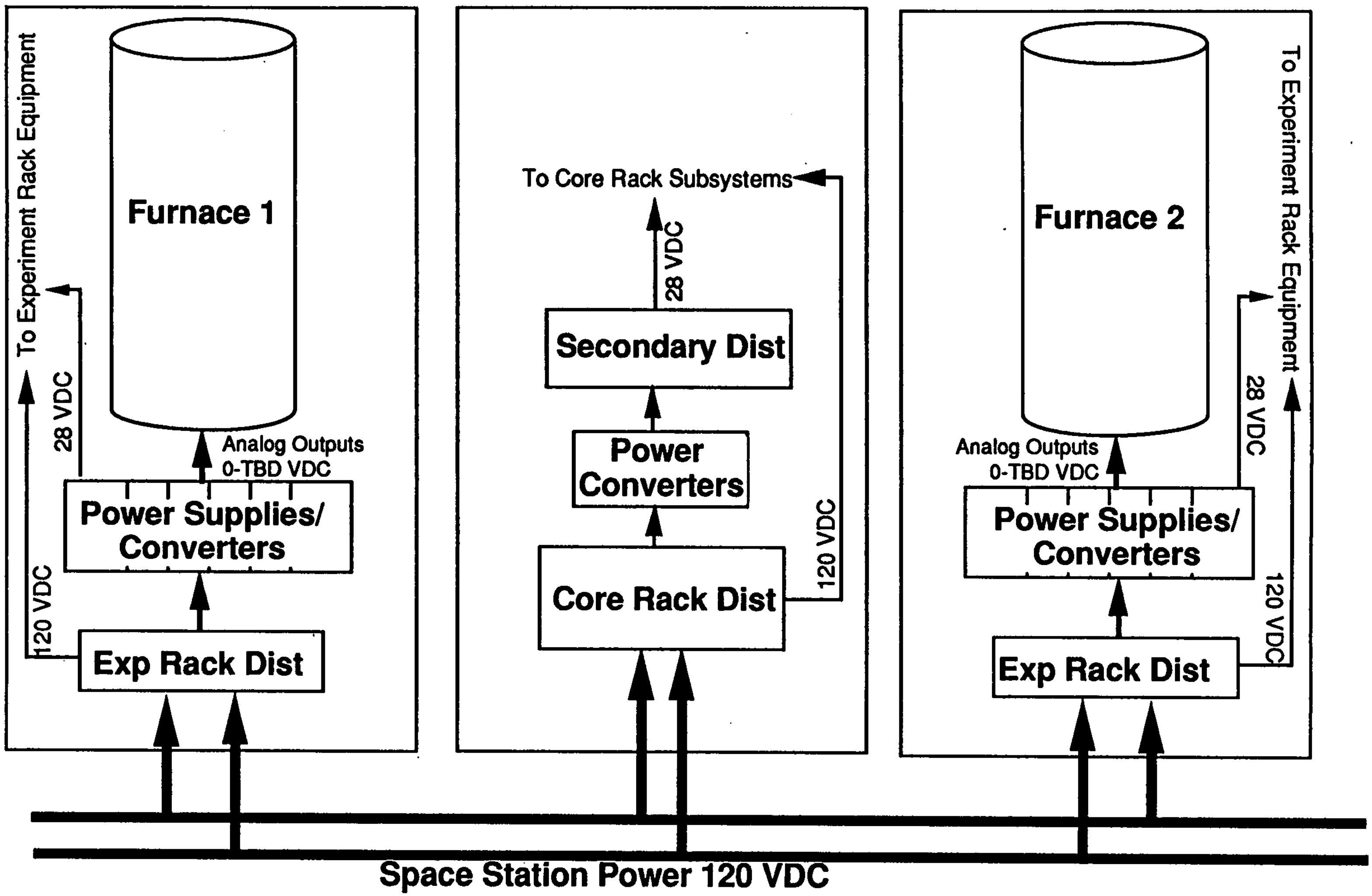


FIGURE 3-2. DISTRIBUTED PCDS CONCEPT

amount of power available to the rack location. For example, 12 kW capability would be available at the core but none of this power would be available to furnace modules since no interrack power cabling is utilized by the distributed design. This 12 kW of power would be available only to core rack equipment.

Difficulties associated with crew maintenance of the SSFF are increased by the distributed concept. Since components are spread among the three racks access to equipment would be more involved. Troubleshooting would require the crew to move test equipment and tools during the operation. Rack fold down is simplified in the distributed concept due to the low number of interrack connections. Rack installation and removal is more difficult due to each rack's requirement to be connected to and disconnected from the SSF power buses.

The distributed PCDS would increase system mass relative to the centralized concept. Total system mass would increase since each rack contains a dedicated power distribution system.

ORU sizes would be decreased by the distributed PCDS and the number of ORUs would be increased. Although the number of ORUs would be increased, the size and complexity would decrease thus improving the reliability of the individual ORU and reducing the probability of failure. Trouble-shooting failures would be simplified in a distributed scheme since specific functions can be isolated to a specific rack location. ORU changeout would be simplified relative to the centralized scheme based on the ease of rack fold down mentioned above.

The greatest downfall of the distributed concept is the lack of reconfigurability offered by dedicating power conditioning in each experiment rack. In the distributed scheme each furnace is power-limited by the capability of the conditioners residing in its rack(barring an elaborate jumper scheme to route one experiment racks' conditioned power to the other). In order to allow for a wide range of furnace power requirements, extra power conditioners must be carried in the experiment rack or added at a later date. These extra conditioners take away experiment rack volume(which would be available for FPE) and add mass and volume to the SSFF.

In a distributed scheme, SSFF subsystems would be free to locate components in appropriate locations since power availability is not limited by interrack cabling. TCS cold plate requirements and DMS control requirements for the centralized PCDS would be increased due to distribution systems residing in each rack. DMS would be required to provide distributed intelligence in the experiment rack for PCDS control, thus increasing DMS mass and volume as well as software complexity.

No safety related impacts are foreseen to be associated with the distributed PCDS other than those normally associated with electrical power systems.

Total utilized facility volume would be increased by a distributed PCDS due to the separate power distribution systems within each rack and the supporting structural, DMS, TCS, and EMI shielding components. Experiment rack volume would be used by the distributed PCDS thus

decreasing the volume available for FPE. Core rack SSFF utilized volume would be decreased due to the distribution of PCDS components among the racks. This would free additional volume for SSFF core subsystems.

3.1.3 Hybrid Concept

The disadvantages associated with the centralized and distributed concepts coupled with the tradeoffs associated with choosing one over the other lead to the consideration of a third concept. This concept is called the Hybrid concept since it is essentially a combination of the centralized and distributed concepts. The Hybrid concept is illustrated in Figure 3-3. The majority of the equipment used for conditioning and distribution of power would be located in the core rack with distributors located in each experiment rack.

The PCDS receives power from the SSF EPS only at the core rack but houses distribution equipment in the experiment racks which can be used for future connection to the SSF power buses. Power would be distributed from the core rack to the experiment racks after undergoing any required conditioning. Power modules reside in the core rack in a power "bank" configuration to accommodate conditioning. The module outputs are capable of being routed to each experiment rack as needed or of being combined to power a single rack.

The hybrid concept results in a more complex design than either of the previous mentioned concepts. Since distributors in the core feed distributors in the experiment rack, trip coordination between distributors is very important. Also, PCDS equipment located in the experiment rack will require control and monitoring by DMS. Since power is routed from the core to the experiment racks interrack cabling will be necessary, although less than the pure centralized concept design. With the hybrid concept, cabling between the core rack and experiment racks is required for the transmission of power to heaters and to the experiment rack distributors for subsystem equipment located in the experiment rack. This cabling between racks will impact efficiency.

Furnace developers designing furnaces which would increase the total SSFF power demand above 12 kW could be accommodated by the hybrid PCDS with moderate modifications to the system. By disconnecting power feeds between the core rack and the experiment rack distributor, then feeding these distributors directly from SSF buses, SSFF capability would approach 24 kW (12 kW at core rack, 6 kW at each experiment rack). This additional power in the experiment rack(for experiment rack subsystem equipment) would free power to be conditioned to drive furnace heaters. This power could be routed to either of the furnace modules as required.

Crew maintenance of the SSFF would be required when growth of the PCDS is deemed necessary, to connect to SSF power buses. Changeout and fold down of the racks would be impacted by the interrack cabling required between the core and experiment racks, although not as

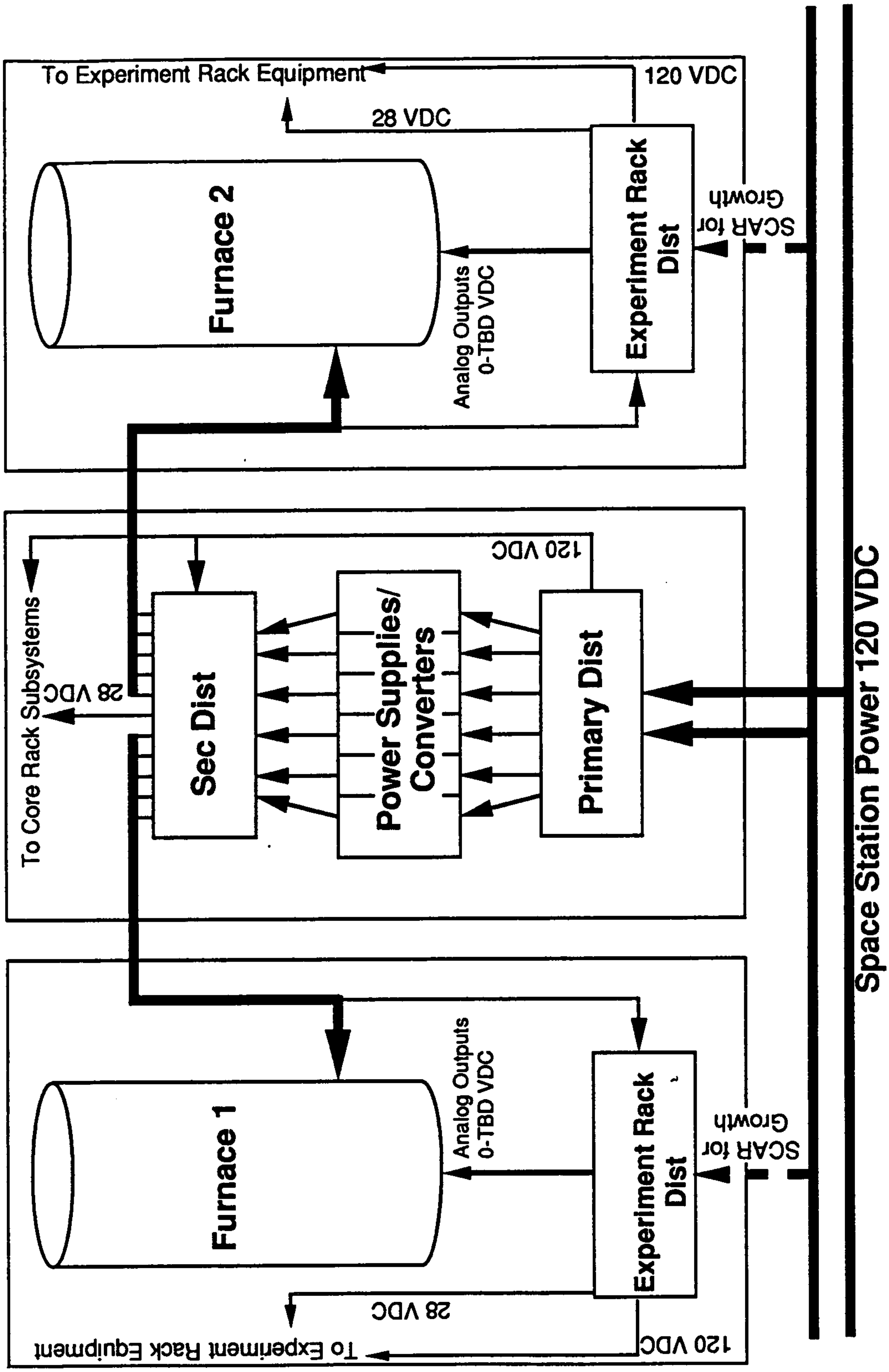


FIGURE 3-3. HYBRID PCDS CONCEPT

severe as the centralized concept. Crew maintenance is also anticipated to reconfigure core conditioner outputs when furnace modules are changed.

The hybrid PCDS would make efficient use of mass, although requiring more than a purely centralized system. Secondary distribution boxes in the experiment racks would increase the total system mass, however a smaller number of excess power converters could be carried due to the reconfigurability of the centralized power banks.

Orbital Replacement Units, would be distributed throughout the system both in the core rack and in the experiment racks, with the majority residing in the core. ORU reliability would be reduced somewhat by the complexity of the system, but ORUs should be fairly accessible in each rack. ORU changeout would be impacted by the difficulty of rack fold down mentioned above. Trouble-shooting failures would be more difficult than in a centralized scheme.

Perhaps the greatest advantage of the hybrid concept is the reconfigurability offered by locating power conditioning for furnace heaters in the core rack. In the hybrid scheme, conditioned power from the core rack may be divided and routed to furnaces as their requirements deem necessary. Theoretically, all conditioned power could be routed to a single experiment rack to drive a high power furnace. The placement of distribution boxes in each experiment rack, which can be fed directly from the EPS if necessary, will allow the power capability of the SSFF to grow.

TCS cold plate requirements and DMS control requirements for the hybrid PCDS would be increased due to the placing of PCDS components in the experiment rack. DMS would be required to provide distributed intelligence in the experiment rack for PCDS control which increases software complexity.

No safety related impacts are foreseen to be associated with the hybrid PCDS other than those normally associated with electrical power systems.

Total utilized facility volume would be slightly less than the distributed concept and slightly greater than the centralized. The majority of PCDS utilized volume would be in the core rack since most PCDS components reside there. Experiment rack volume is freed for furnace module use by concentrating PCDS conditioning in the core. This could result in a possible impact on SSFF core subsystems.

3.2 SELECTED CONCEPT

3.2.1 Descriptions

Of the three considered PCDS concepts it is clear, when judged by the stated criteria of Section 3.1, that the Hybrid Concept is the design which will most accurately meet the requirements of the SSFF. This concept offers the maximum flexibility in accommodating the range of furnace modules listed in the SCRD.

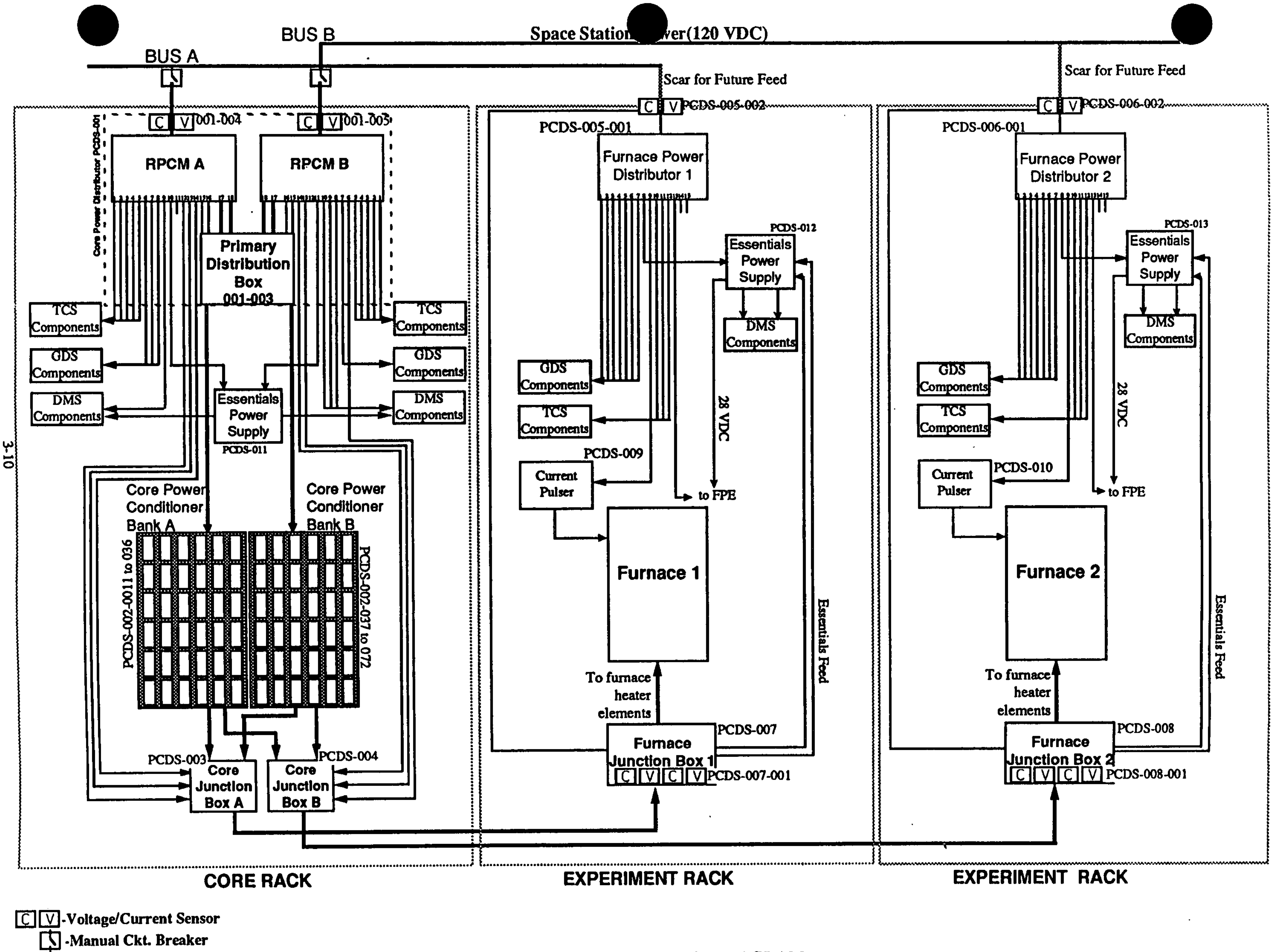


FIGURE 3-4. PCDS BLOCK DIAGRAM

Based upon this selection, the PCDS baseline conceptual design is illustrated in the block diagram in Figure 3-4. 120 VDC SSF power is brought into the facility at the core rack through RPCMs. The RPCMs are Station provided and, after trade study results, may be replaced with a SSFF designed power distributor. Power is routed by the Core Power Distributor which is made up of the RPCMs and the Primary Distribution Box (for switching of the Core Power Conditioner Modules). It is from the Core Power Distributor that power is distributed to core rack equipment, and to the Core Junction Boxes for routing to experiment racks. The Core Power Conditioner is composed of seventy-two, 100 W, controllable power modules which power the furnace heaters. Each module converts 120 VDC to an analog output of 0-12 VDC. Each module will be feedback controlled by the DMS, dependent on furnace temperature requirements. The outputs from the Core Power Conditioner are fed to the Core Junction Boxes. The Core Junction Boxes configure power module outputs depending on furnace needs. It is here that module outputs will be stacked in series in order to accommodate various furnace heaters. The Core Junction Boxes will be reconfigurable(by crew or ORU changeout) in order to change module outputs to accommodate furnace needs. In addition to module outputs, any other feeds (120 VDC) which must terminate in experiment racks will be routed by the Core Junction Boxes. Power will be routed by wiring harnesses between the Core Junction Boxes and the Furnace Junction Boxes. All power lines to experiment racks will be accommodated by 4 connectors to each experiment rack. In each experiment rack resides a Furnace Junction Box. This assembly houses voltage and current sensors for heater power monitoring and provides the interface to which user furnaces plug. This assembly will also route power to the Furnace Power Distributor(FPD), which serves the same function in the experiment rack as the Core Power Distributor in the core rack, and will be a SSFF designed component. Scarring will be placed in the experiment rack so that SSF 120 VDC power may enter the SSFF at the experiment rack when growth of the SSFF dictates a need for additional power feeds from SSF.

3.2.2 Components Descriptions

Table 3-1 lists the components of the PCDS. Each component is assigned to an assembly and an assembly number. This number corresponds to those detailed in Figure 3-4. Appendix C contains detailed specification sheets for typical components meeting the requirements of the current conceptual design.

3.2.2.1 Core Power Distributor, Junction Boxes - Power Distribution for the SSFF is accomplished through the use of SSF provided RPCMs (or similar equipment) in conjunction with the Primary Distribution Box(PDB). Distribution within the core is provided by two RPDAs (which will accommodate at least one Type V hybrid RPCM each, two each if needed) in conjunction with the SSFF designed PDB. Distribution in each experiment rack will be provided by the Furnace Power Distributor(FPD), a SSFF designed box similar in function to the RPCM.

TABLE 3-1. PCDS COMPONENTS LIST

	ASSEMBLY	ID#	SUBCOMPONENTS	DESCRIPTION
PCDS-001	Core Power Distributor(CPD)	PCDS-001-001	Remote Power Distribution Assembly (RPDA-A)	Receives 120 VDC power from SSF Bus A and distributes to subsystem equipment associated with operation of furnace module #1. Distributes other feeds as needed. Accommodates 1 or 2 RPCMs.
		PCDS-001-002	Remote Power Distribution Assembly-B (RPDA-B)	Receives 120 VDC power from SSF Bus B and distributes to subsystem equipment associated with operation of furnace module #2. Distributes other feeds as needed. Accommodates 1 or 2 RPCMs.
		PCDS-001-003	Primary Distribution Box(PDB)	Receives 120 VDC power from RPDA -A & B Distributes power to power modules in CPC. Switches each module on/off.
		PCDS-001-004	Voltage/Current Sensor Package	Monitors power fed to RPDA-A from SSF Bus A.
		PCDS-001-005	Voltage/Current Sensor Package	Monitors power fed to RPDA-B from SSF Bus B.
PCDS-002	Core Power Conditioner	PCDS-002-001 to 036	CPC Bank A	Condition power for furnace heater elements, individually or stacked in series. Composed of 36, 100 w modules.
		PCDS-002-037 to 072	CPC Bank B	Condition power for furnace heater elements, individually or stacked in series. Composed of 36, 100 w modules.
PCDS-003	Core Junction Box-A (CJB-A)			Routes power to experiment racks depending on furnace requirements. May be reconfigured/replaced. Easily accessible.
PCDS-004	Core Junction Box-B (CJB-B)			Routes power to experiment racks depending on furnace requirements. May be reconfigured/replaced. Easily accessible.

TABLE 3-1. PCDS COMPONENTS LIST (Continued)

	ASSEMBLY	ID#	SUBCOMPONENTS	DESCRIPTION
PCDS-005	Furnace Power Distributor-1 (FPD-1)	PCDS-005-001	FPD-1	Distributes 120 VDC power to experiment rack equipment.
		PCDS-005-002	Voltage/Current Sensor Package	Monitors power fed to FPD-1
PCDS-006	Furnace Power Distributor-2 (FPD-2)	PCDS-006-001	FPD-2	Distributes 120 VDC power to experiment rack equipment.
		PCDS-006-002	Voltage/Current Sensor Package	Monitors power fed to FPD-2
PCDS-007	Furnace Junction Box-1(FJB-1)	PCDS-007	FJB-1	Provides interface for furnace connection. Also houses power monitoring equipment-current/voltage sensors.
		PCDS-007-001	Voltage/Current Sensors(32 pairs)	Monitor heater power being delivered by PCDS to furnace module #1. Used as control parameter for power modules.
PCDS-008	Furnace Junction Box-2(FJB-2)	PCDS-008	FJB-2	Provides interface for furnace connection. Also houses power monitoring equipment-current/voltage sensors.
		PCDS-008-001	Voltage/Current Sensors(32 pairs)	Monitor heater power being delivered by PCDS to furnace module #2. Used as control parameter for power modules.
PCDS-009	Current Pulser-1 (CP-1)			Includes all electronics required to deliver current pulse to furnace module #1 as stated in SCRD. Concept determined by detailed design(phase C/D).
PCDS-010	Current Pulser-2 (CP-2)			Includes all electronics required to deliver current pulse to furnace module #2 as stated in SCRD. Concept determined by detailed design(phase C/D).
PCDS-011	Essentials Power Supply (EP)			Provides Electrical isolation between feeds where 2 buses are tied together for safing power. Composed of 2 DC-DC converters and RPCs for switching of loads.

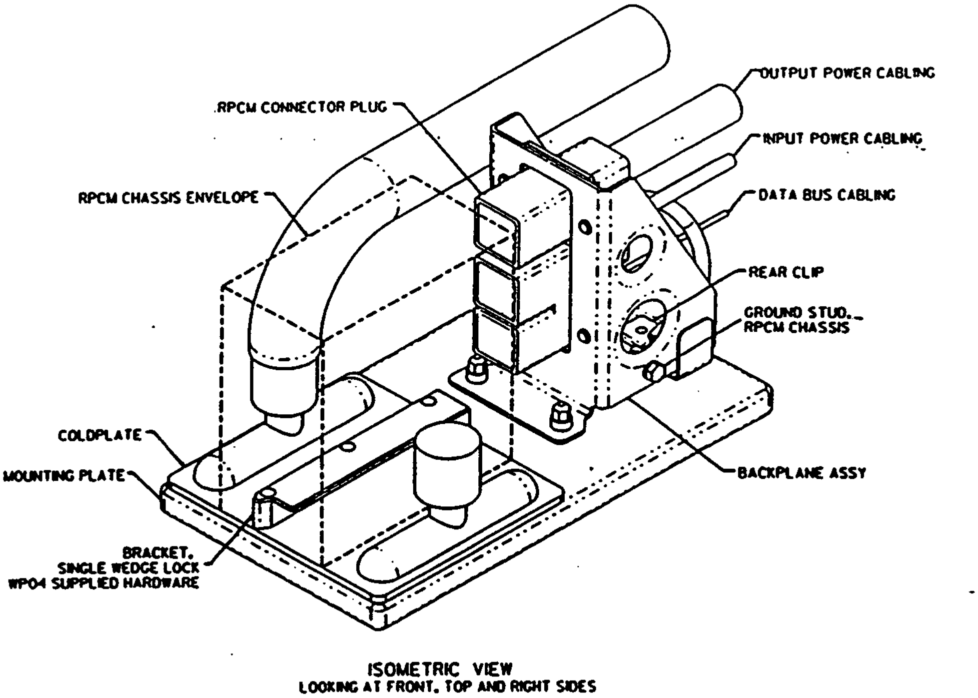
TABLE 3-1. PCDS COMPONENTS LIST (Continued)

	ASSEMBLY	ID#	SUBCOMPONENTS	DESCRIPTION
PCDS-012	Essentials Power Supply			Provides Electrical isolation between feeds where 2 buses are tied together for essentials power. Composed of 3 DC-DC converters and RPCs for switching of loads. 2 converters for safing power, 1 for utility 28 VDC for FPE.
PCDS-013	Essentials Power Supply			Provides Electrical isolation between feeds where 2 buses are tied together for essentials power. Composed of 3 DC-DC converters and RPCs for switching of loads. 2 converters for safing power, 1 for utility 28 VDC for FPE.

Core Junction Boxes will route power from the core to the experiment racks. Furnace Junction Boxes will serve as interface panels for furnace heaters, as well as route power from the core to the FPD for distribution to distributed core subsystem equipment. Figure 3-5 illustrates SSF provided RPDAs.

Since SSF does not provide a dedicated essentials bus to 12 kW racks, all equipment essential for safe shutdown will be powered by tying Buses A and B together. This will ensure that if one bus is lost, the other may be used to shutdown the facility. The SSF Electrical Power Specifications and Standards SSP30482 require that 1 MΩ of electrical isolation be maintained between buses at all points throughout the payloads electrical system. To meet this requirement, the SSFF PCDS will assign loads to either one bus or the other. Bus A will power equipment necessary to maintain normal operations of furnace #1 while Bus B will power equipment necessary to maintain normal operations of furnace #2. Equipment which must be powered to accomplish safe shutdown and equipment which must be powered to maintain normal operations of either of the furnace modules will combine one feed from each of the buses. This will be accomplished through the use of transformer coupled power supplies, break-then-make switches, or battery packs. The results of a detailed trade study will determine which method is the most appropriate. Redundant components within subsystems will be fed from separate buses. The division of equipment between buses and the coupling methods determined by trade study will ensure that 1 MΩ isolation is maintained between the buses at all points throughout the system. Figure 3-6 illustrates an example of how SSFF loads will be divided between buses. These load assignments are based on the current SSFF subsystem concepts. The current PCDS concept uses

Single Position Layout



Two Position Layout

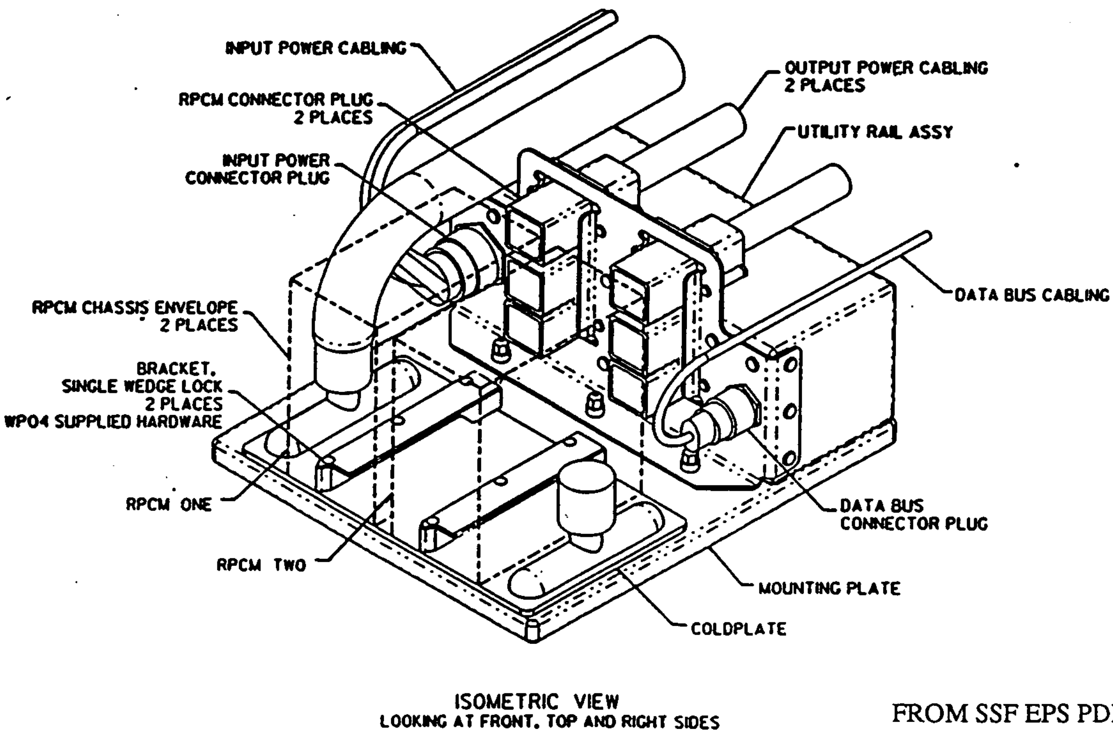


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FIGURE 3-5. SSF PROVIDED REMOTE POWER DISTRIBUTION ASSEMBLY

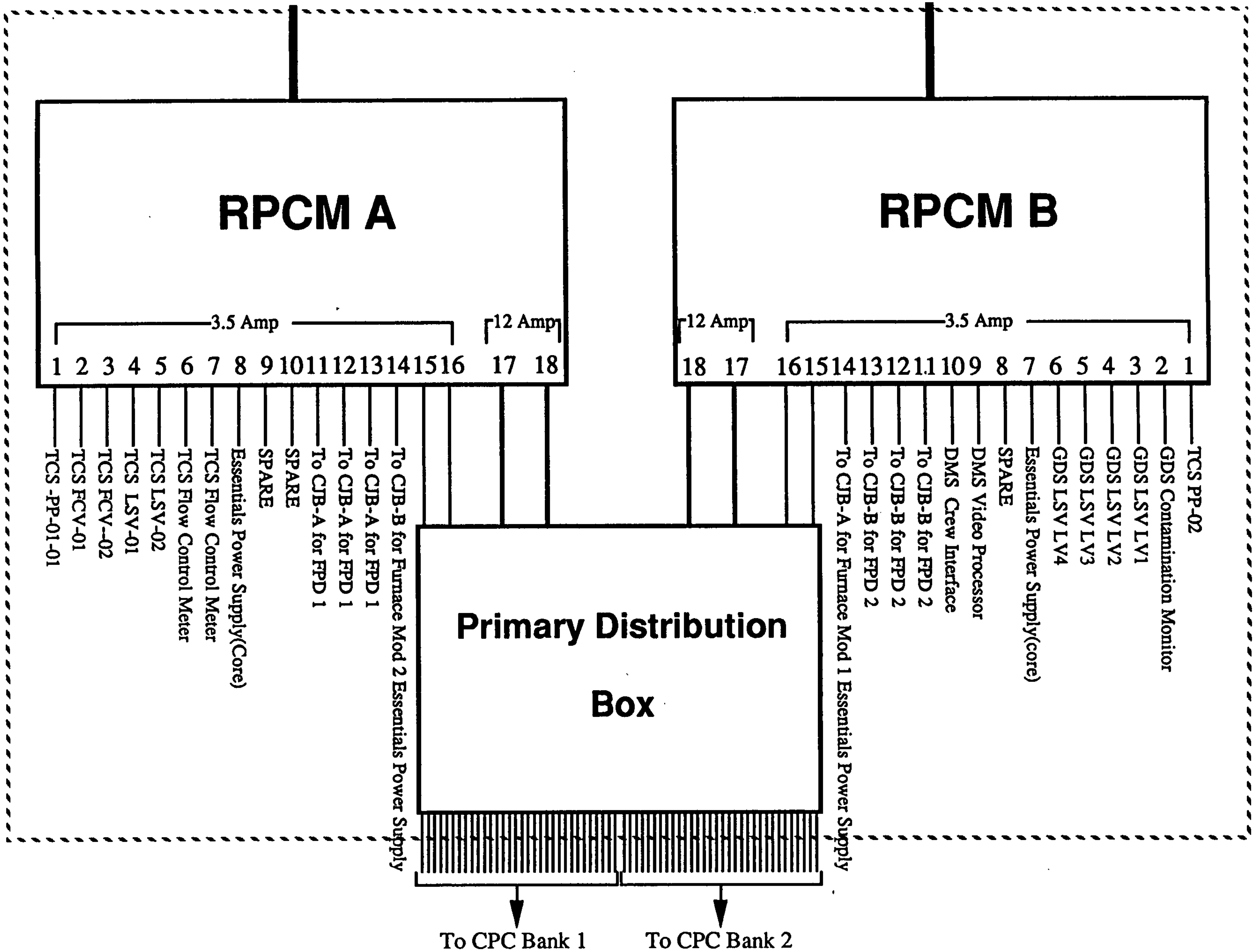


FIGURE 3-6. CORE POWER DISTRIBUTOR TYPICAL LOAD ASSIGNMENTS

DC-DC power supplies to tie Bus A and Bus B together in an Essentials Power Supply located in each rack.

By assigning furnace module #1 to Bus A and furnace module #2 to Bus B, SSFF operations can be ensured (on a limited level) when one bus's capabilities are reduced due to extreme loading. For example, if Bus B could not meet demand, SSF DMS may request non-essential users of Bus B to scale back usage. SSFF could then discontinue operations of furnace module #2 and use only Bus A while continuing normal operations of furnace module #1.

The Primary Distribution Box which feeds the Core Power Conditioner is necessary to provide independent energizing of each of the 72 power modules. Although, an input signal from DMS will determine each modules output, a closed switch on the input power side of the module, even when the output is 0 VDC will cause some consumption in the internal circuit. It is,therefore, desirable to have the capability to energize only those modules which will be required for furnace operations. Also, to prevent a single module failure from impacting the entire bank, individual switching is necessary for circuit protection. The switches used to perform this energizing will be housed in either one or two distribution boxes (one will be adequate if the necessary isolation can be maintained between switches fed from Bus A and switches fed from Bus B). These solid state switches will be fed from the appropriate RPCM feeds and will be controlled by SSFF DMS. Seventy-two switches will be housed to perform the on/off control of the modules, with necessary space reserved for the addition of power modules for future growth. The Primary Distribution Box is illustrated in Figure 3-7.

The functions of the RPCMs and Primary Distribution Box may be more efficiently accomplished by a single distribution box designed by SSFF. This determination will be left to a detailed trade analysis of such a design versus the SSF provided RPCMs.

Power to the experiment racks will be routed via the Core Junction Boxes. These junction boxes will route power to the furnace heaters, as well as 120 VDC utility power for use by the furnace module, and power used by distributed core subsystem equipment. Each box will be reconfigurable so that CPC power may be redirected to either furnace module #1 or #2. A Core Junction Box is illustrated in Figure 3-8.

Inside each experiment rack a Furnace Junction Box will serve as an interface point for furnace heater elements. The Furnace Junction Box will also serve as an interface for any 120 VDC utility power needed, and will route power to the FPD for subsystem use. The FPD will be a SSFF designed distribution box which will be similar in function to the SSF RPCM. The switches of this box will be trip coordinated with those of the core rack RPCM. The Furnace Junction Box and Furnace Power Distributor are illustrated in Figures 3-9 and 3-10 respectively. An example of how loads in the experiment rack will be assigned feeds from the FPD is shown in Figure 3-11.

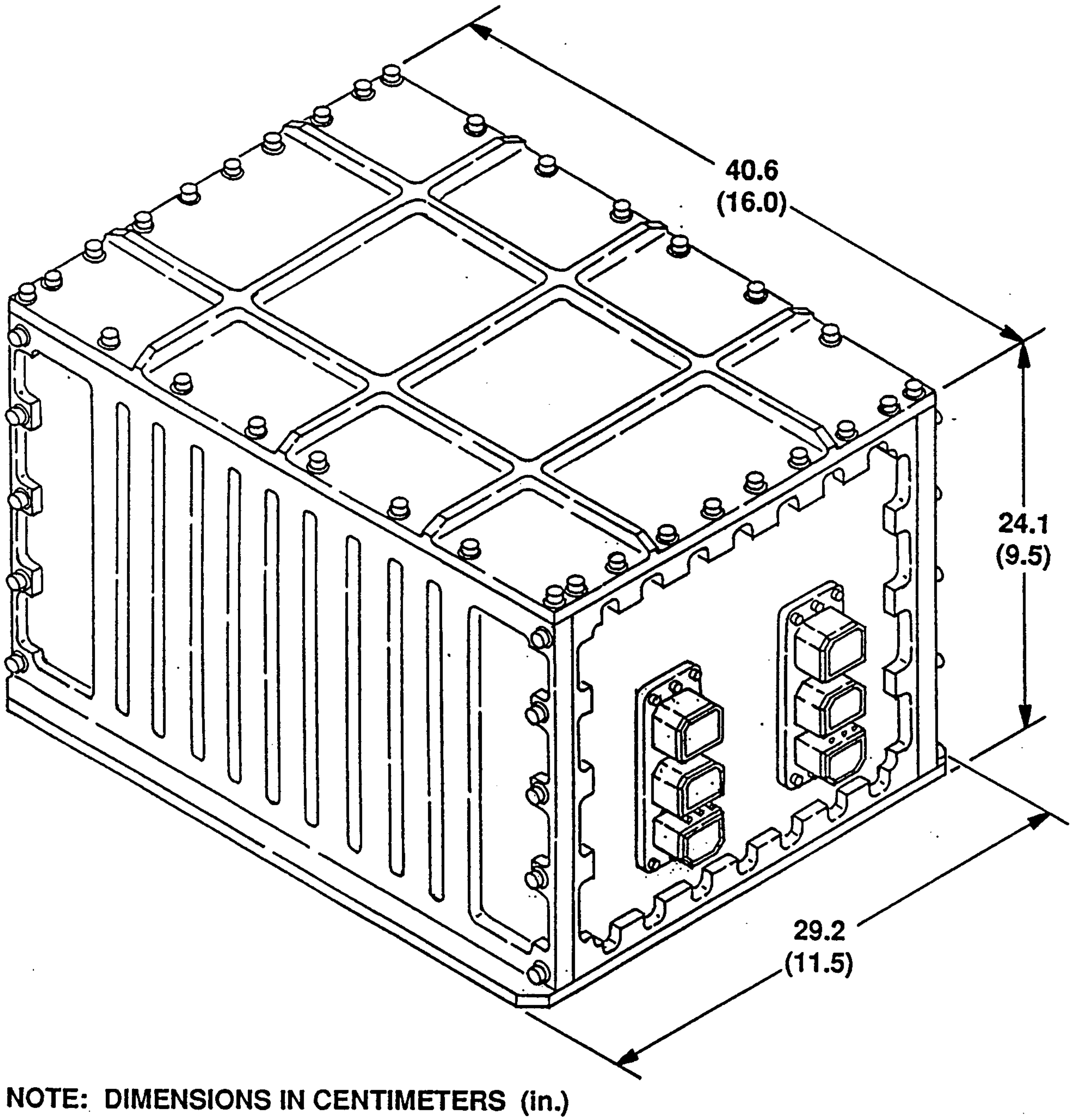


FIGURE 3-7. PRIMARY DISTRIBUTION BOX PACKAGING CONCEPT

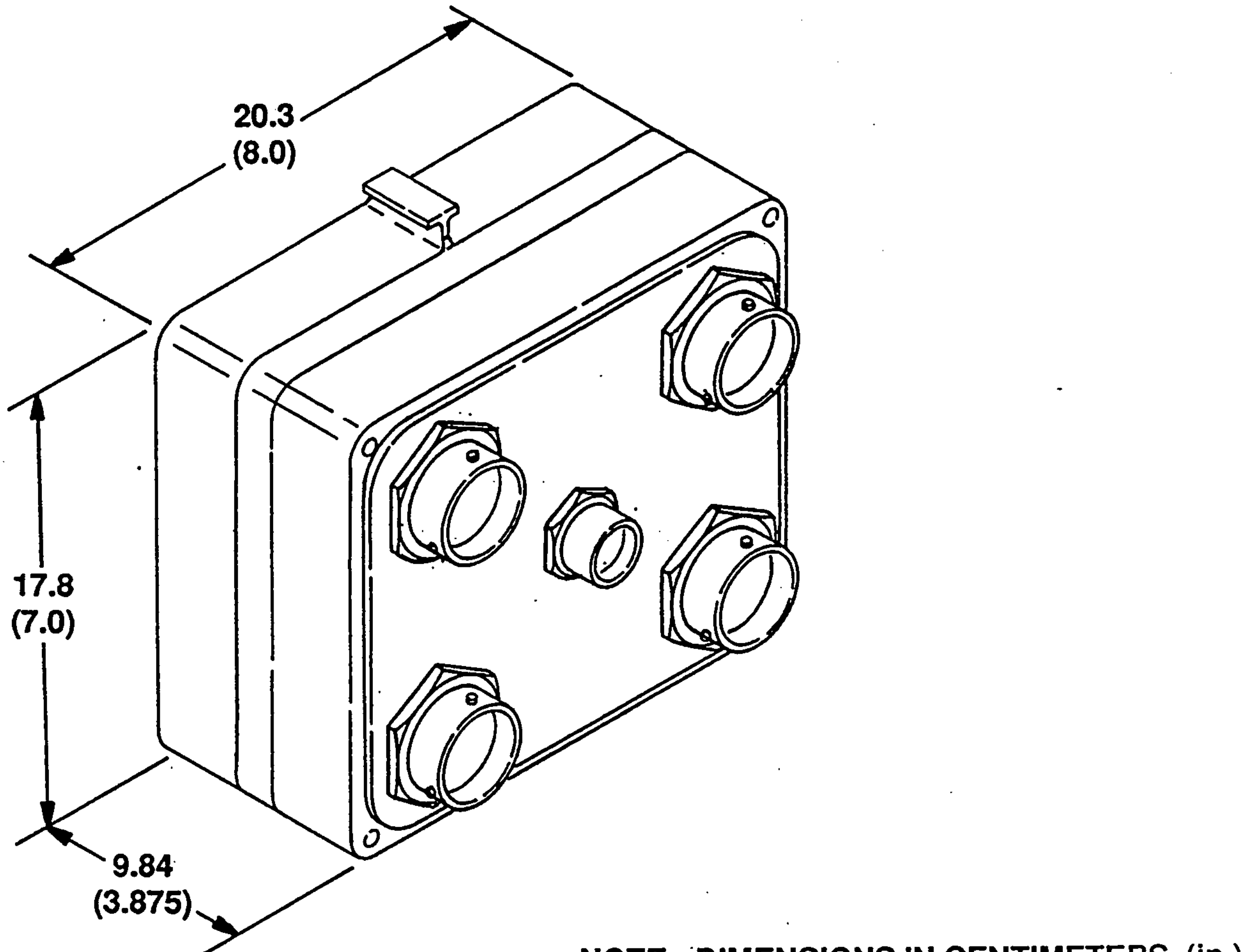


FIGURE 3-8. CORE JUNCTION BOX PACKAGING CONCEPT

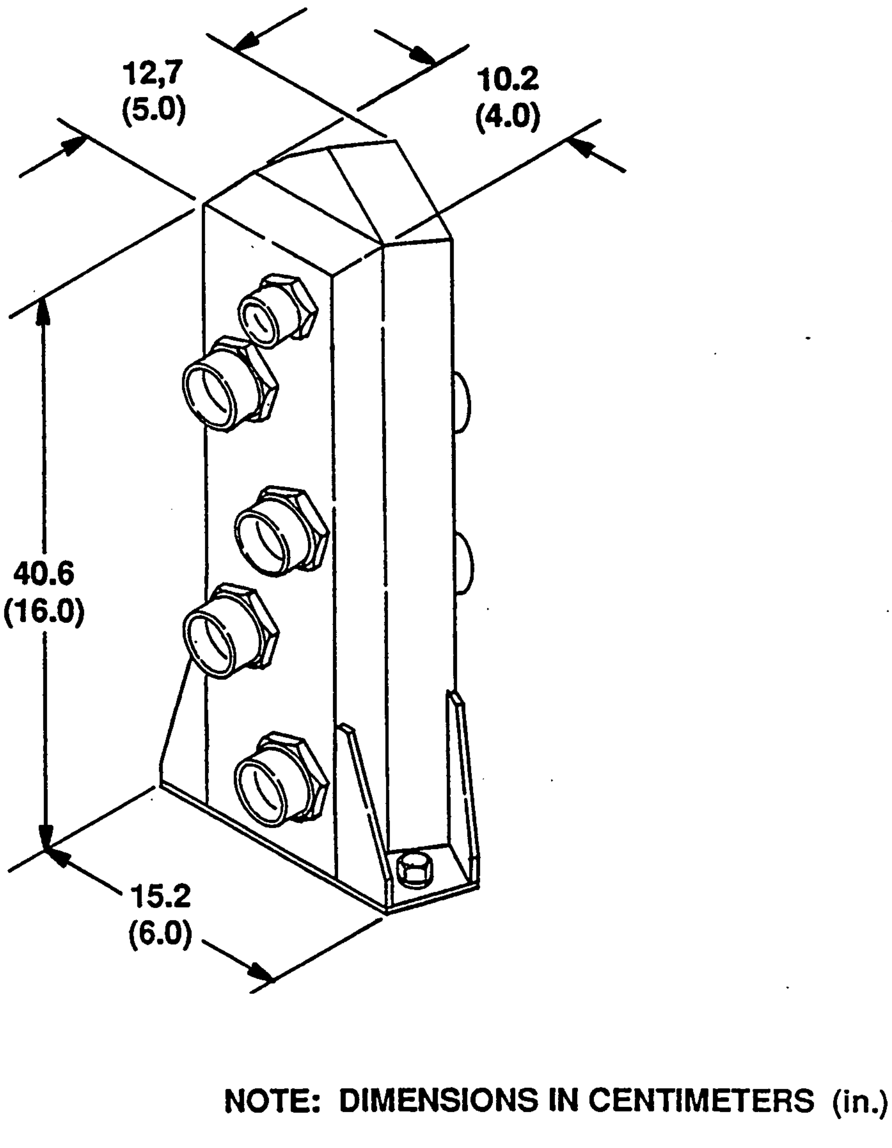
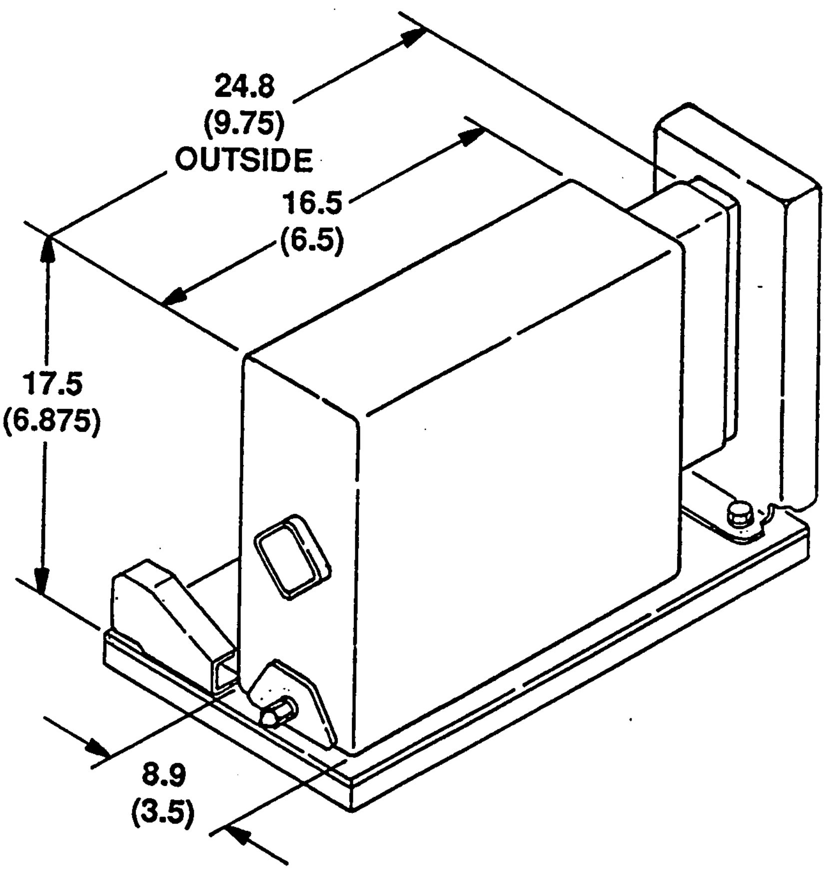


FIGURE 3-9. FURNACE JUNCTION BOX PACKAGING CONCEPT



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3-10. FURNACE POWER DISTRIBUTOR PACKAGING CONCEPT

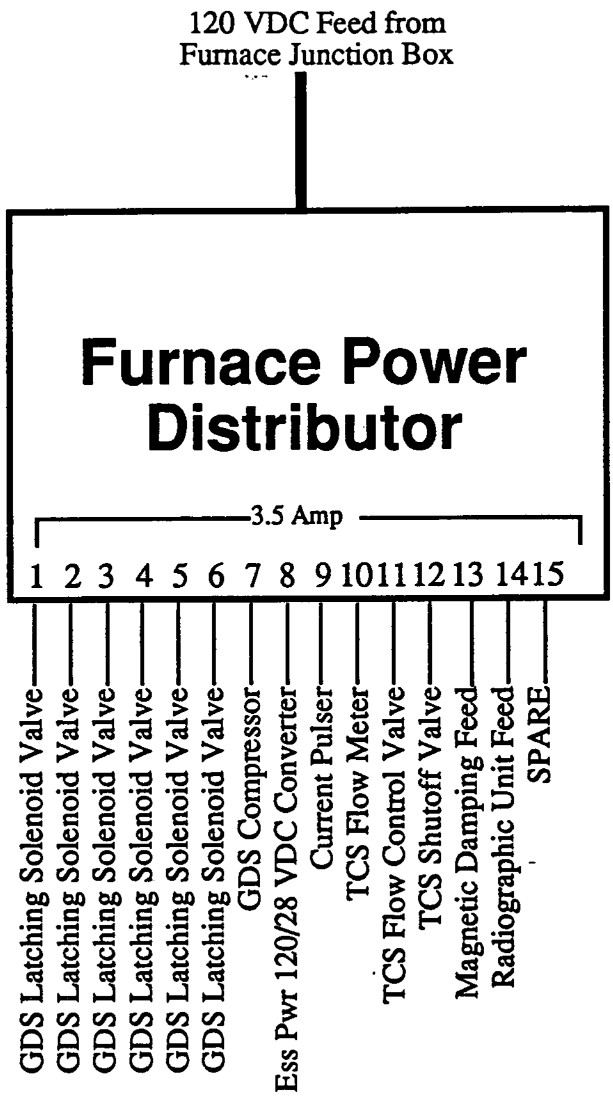


FIGURE 3-11. FURNACE POWER DISTRIBUTOR TYPICAL LOAD ASSIGNMENTS

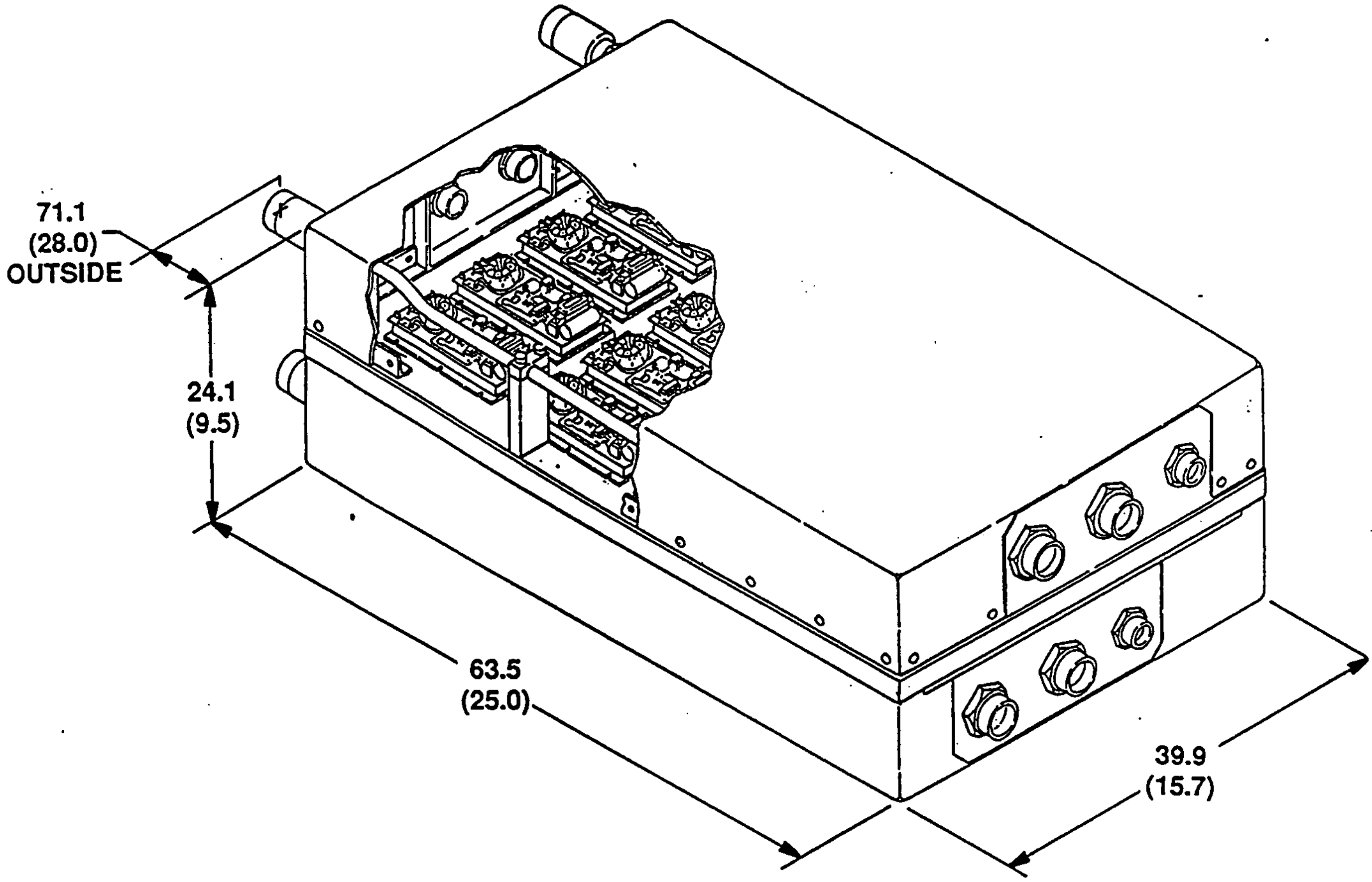
3.2.2.2 <u>Core Power Conditioner</u> - The Core Power Conditioner provides power to the furnace heater elements. The CPC is composed of two banks of 36, 100 W, DC-DC power converter modules. A CPC Bank is illustrated in Figure 3-12. Each module is independently controlled/monitored and will output a voltage of 0-12 VDC (up to 20 A) when receiving an input of 120 VDC. By using banks of independently controlled modules, flexibility to power various types of furnace heaters is provided. Although the number of modules was determined based on the needs of CGF and PMZF (see Appendix B), all 72 modules may be reconfigured by the Core Junction Boxes to accommodate a wide range of furnaces. Modules can power a heater element each, for example, giving the capability to power a 72 zone furnace comprised of 100 W per zone. Module outputs may also be connected in series at the Core Junction Boxes so that a furnace with a low number of high power zones may be accommodated. This is illustrated in Figure 3-13.

Voltage source, current limited, power modules were selected for several reasons. High current, low voltage, modules would require much larger line sizes routed from modules to experiment racks, thus limiting (if not preventing) the ability to interrack connect and increasing inefficiencies associated with transmission losses. Furnace developers are limited in the size of wire which can be accommodated in heater elements, thus physically current limiting the heaters (A typical maximum approaching 20 A). By using voltage sources, PCDS can accommodate heaters as small as 6 VDC at 20 A (120 watts) or heaters in the range of 60 VDC at 20 A (1200 watts).

3.2.2.3 <u>Essentials Power Supplies</u> - Essentials power is accomplished by an Essentials Power Supply(EP) located in each of the SSFF racks. The Essentials Power Supply is illustrated in Figure 3-14. Each EP consists of 2 DC-DC converters which are fed from Bus A and Bus B(via RPCM-A or RPCM-B). These supplies and their accompanying electronics will ensure that 1 Mega Ohm of isolation will be maintained between buses at all times. Diode coupling each converter will allow the Essentials Power Supply to provide a continuous feed to essential DMS equipment when at least 1 bus is delivering adequate power. Converters in the current concept will take 120 VDC power and convert it to 28 VDC to feed DMS components. In addition to essential equipment, any equipment requiring 28 VDC will be fed from the EP. This converted power will be applied by RPCs residing in the supply. Each of the essentials power supplies located in the experiment racks contain an additional 120/28 VDC converter for feeding furnace peculiar equipment.

The results of a detailed engineering analysis and trade study on essentials power will determine whether essentials power might be better served with a 1 to 1 conversion box or with a break-then-make smart switching box.

3.2.2.4 <u>Current Pulsing Equipment</u> - Equipment required to provide current pulsing capability to each furnace will be located in each experiment rack. After detailed design has determined the design requirements of equipment necessary to provide the pulse (as outlined in the



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3-12. CORE POWER CONDITIONER BANK PACKAGING CONCEPT

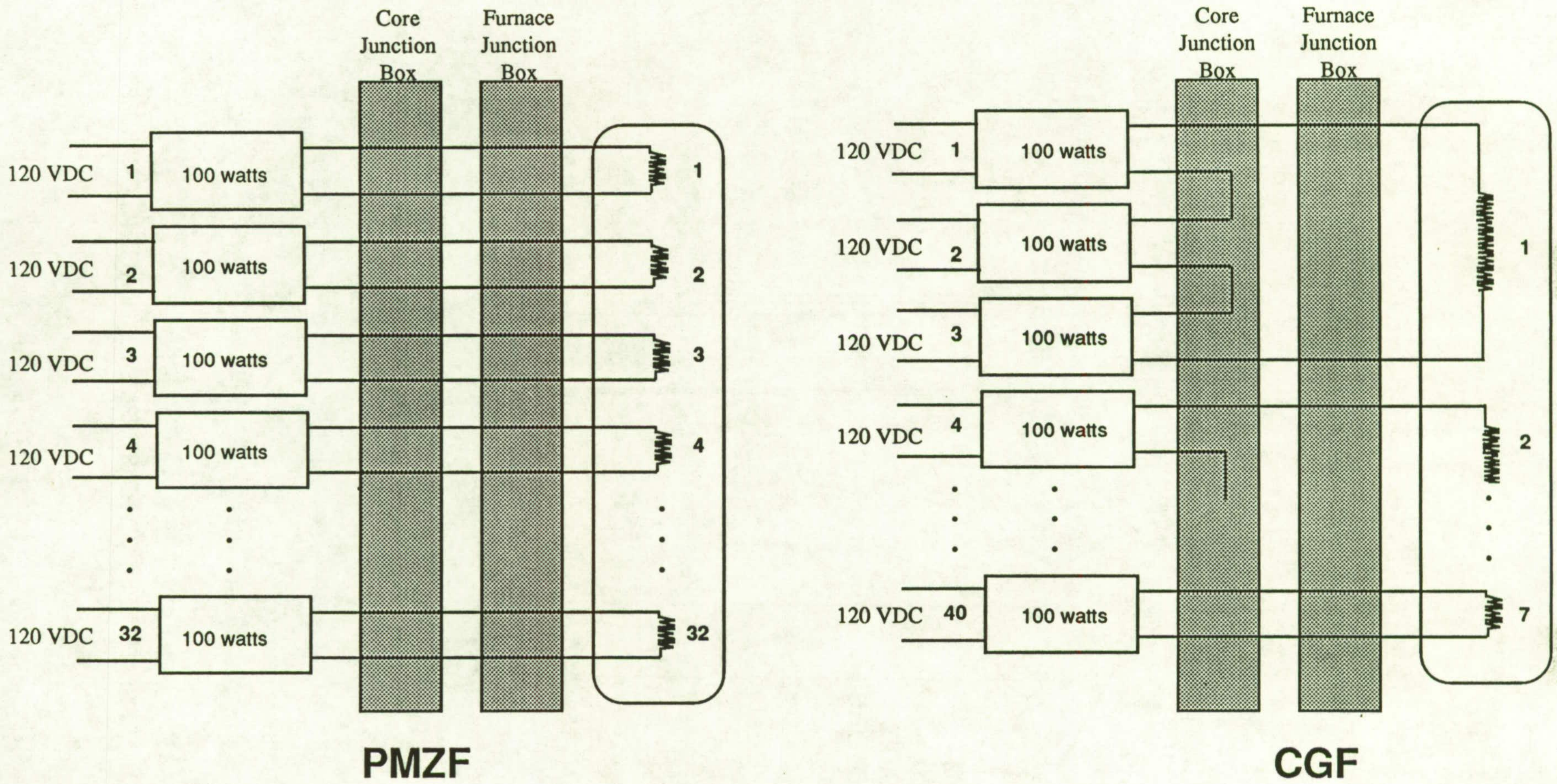


FIGURE 3-13. POWER MODULE CONFIGURATIONS

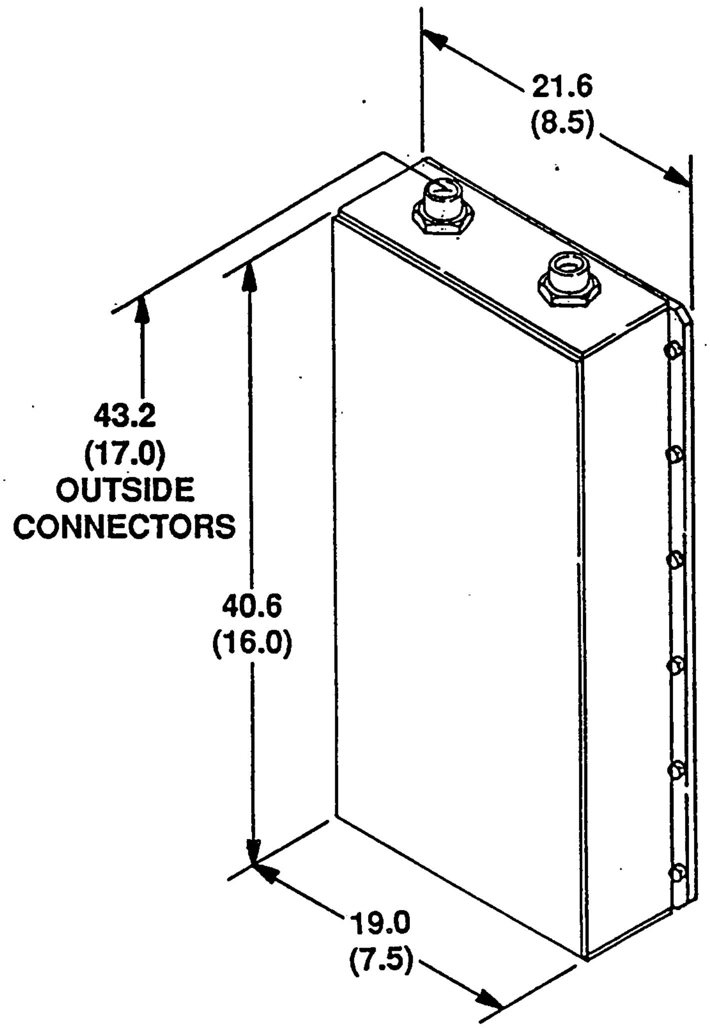


FIGURE 3-14. ESSENTIALS POWER SUPPLY PACKAGING CONCEPT

Science Capabilities Requirements Document), channels on the FPD will be dedicated to providing power to the current pulsing equipment. The current PCDS concept uses placeholder envelope dimensions and resource requirements based on estimates and the time averaged power requirement listed in the SCRD.

The packaged PCDS components are shown integrated into the SSFF core and experiment racks in Figures 3-15 and 3-16 respectively.

3.3 SAFETY

The SSFF PCDS will address safety in two areas. 1) Safe shutdown of the SSFF and 2) Protection of internal SSFF subsystems from internal failures.

The PCDS will support safe shutdown of the SFFF subsystems by providing an essentials power supply in each rack. The essentials power supply combines two independent feeds originating from SSF EPS while maintaining all the required isolation and protection requirements. This power supply will provide power to any equipment necessary for the safe shutdown of the SSFF. Since it is assumed that at no time will both SSF buses be lost simultaneously, the essentials power supply will ensure that safing power is at all times available to essential shutdown equipment.

The PCDS will protect SSFF equipment from internal failures through circuit protection. Current limited switches will isolate failed equipment from other healthy equipment on the power distribution network. This will prevent a single failure from impacting the entire facility electrically. Status indicators on switches will notify DMS when components have been tripped off the network so that appropriate action can be initiated.

No safety related impacts are foreseen to be generated by the baseline PCDS concept other than those normally associated with electrical power systems.

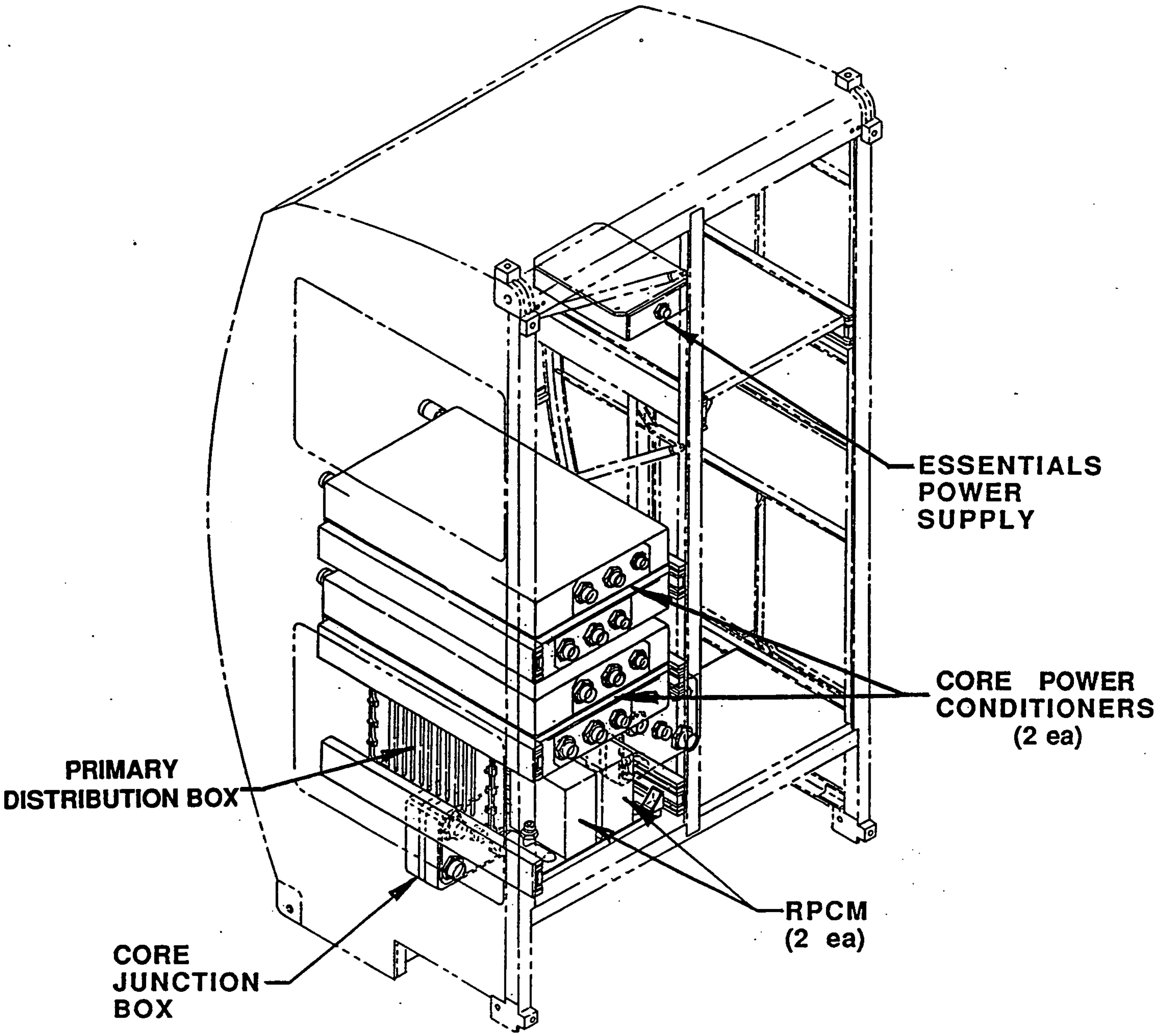


FIGURE 3-15. PCDS INTEGRATED CORE RACK COMPONENTS

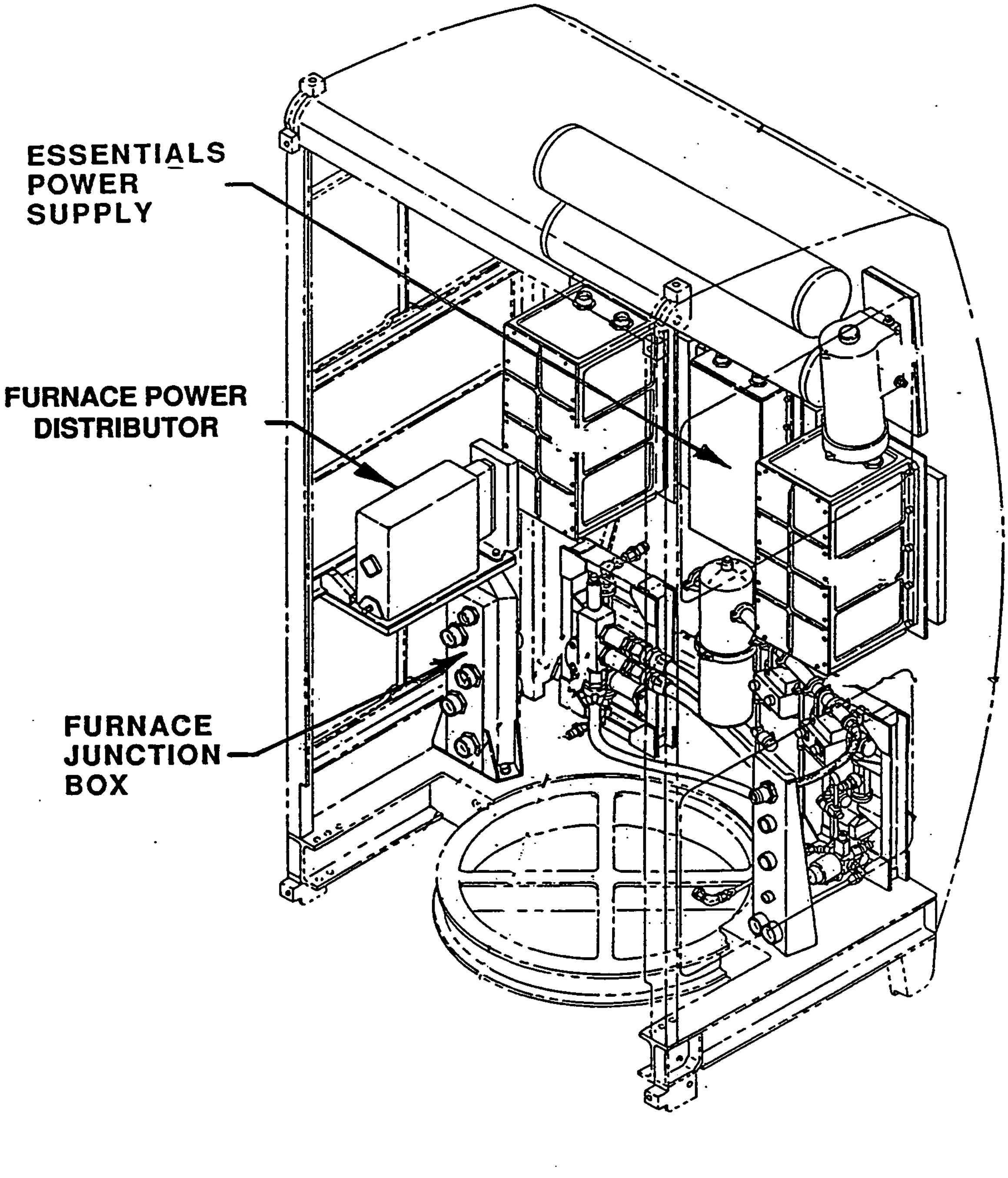


FIGURE 3-16. PCDS INTEGRATED EXPERIMENT RACK COMPONENTS

4. RESOURCE REQUIREMENTS

4.1 POWER

Power consumed by the PCDS is due to equipment inefficiencies plus power required for sensors and biasing of electronics. Table 4-1 details the power consumption of the PCDS during the peak draw of the SSFF as detailed in Table 2-2.

TABLE 4-1. PCDS POWER CONSUMPTION

COMPONENT	POWER CONSUMPTION (watts)
Centralized Equipment	
RPCM(2)	37.4
Primary Distribution Box	73.9
Core Power Conditioner	1300.0
Essentials Power Supply	205.3
Voltage/Current Sensor(4)	4.0
Line & Connector Loss	290.4
Distributed Equipment	
Furnace Power Distributor(2)	37.4
Essentials Power Supply(2)	180.7
Current Pulser(2)	80.0
Voltage/Current Sensor(132)	132.0
Line & Connector Loss	348.7
TOTAL	**2,689.8**

4.2 MASS

Mass for the PCDS design is estimated in Table 4-2.

4.3 VOLUME

Volume for the PCDS design is estimated in Table 4-3.

4.4 HEAT REJECTION

Since power consumption associated with the PCDS is due primarily to equipment inefficiencies, heat rejected by the PCDS is assumed to be 100% of the power listed in Table 4-1.

4.5 DMS

The DMS requirements of the PCDS are detailed in Table 4-4.

TABLE 4-2. PCDS MASS ESTIMATES

	kg	lbs
Centralized Equipment		
Core Power Distributor	20.9	45.98
RPCM(2)		
Primary Distribution Box		
Core Power Conditioner	47.2	103.84
Core Junction Boxes(2)	38.2	84.04
Essentials Power Supply	3.2	7.04
Voltage/Current Sensor(4)	2.0	4.4
Line & Connector	11.3	24.86
Subtotal	122.8	270.2
Distributed Equipment		
Furnace Junction Box(2)	19.1	42.02
Furnace Power Distributor(2)	14.5	31.9
Essentials Power Supply(2)	6.4	14.08
Current Pulser(2)	27.2	59.84
Voltage/Current Sensor(132)	66.0	145.2
Line & Connectors	7.7	16.94
Subtotal	140.9	310
Total Mass	263.7	580

TABLE 4-3. PCDS VOLUME ESTIMATES

COMPONENTS	m^3	$ft.^3$
Centralized Equipment:		
Core Pwr Distributor (CPD)		
-RPCMs	0.047	1.674
-Primary Distribution Box	0.029	1.009
Core Power Conditioner (CPC)	0.122	4.313
Core Junct Box-A (CJB-A)	0.004	0.126
Core Junct Box-B (CJB-B)	0.004	0.126
Essentials Power Supply	0.018	0.626
Voltage /Current Sensors*	0.000	0.000
Line & Connectors	0.003	0.060
Subtotal	0.227	7.934
Distributed Equipment:		
Current Pulser	0.180	6.460
Furnace Pwr Dist. (FPD)	0.008	0.273
Furnace Junction Box (FJB)	0.016	0.554
Essentials Power Supplies	0.035	1.252
Voltage/Current Sensors*	0.000	0.000
Line & Connectors	0.002	0.080
Subtotal	0.241	8.619
Total Volume	**0.468**	**16.553**

*Sensors housed within PCDS boxes.

TABLE 4-4. DMS INTERFACES

COMPONENT ID	NOMENCLATURE	OUTPUTS	TYPE	INPUTS	TYPE
PCDS-001-001	RPCM A	18	serial	18	serial
PCDS-001-002	RPCM B	18	serial	18	serial
PCDS-001-003	Primary Distribution Box	72	serial	72 72	serial excitation
PCDS-001-004	Voltage/Current Sensor	2	analog	2	excitation
PCDS-001-005	Voltage/Current Sensor	2	analog	2	excitation
PCDS-002-001 to 036	Core Power Conditioner Bank A	36	serial	36	serial
PCDS-002-037 to 072	Core Power Conditioner Bank B	36	serial	36	serial
PCDS-005-001	Furnace Power Distributor 1	15	serial	15	serial
PCDS-005-002	Voltage/Current Sensor	2	analog	2	excitation
PCDS-006-001	Furnace Power Distributor 2	15	serial	15	serial
PCDS-006-002	Voltage/Current Sensor	2	analog	2	excitation
PCDS-007-001	Voltage/Current Sensors	64	analog	64	excitation
PCDS-008-001	Voltage/Current Sensors	64	analog	64	excitation
PCDS-009	Current Pulser	TBD	TBD	TBD	TBD
PCDS-010	Current Pulser	TBD	TBD	TBD	TBD

4.6 STRUCTURAL

The PCDS components will require adequate mounting structures within the racks for all components to survive flight and ground handling loads.

4.7 OTHERS

No other resource requirements are identified at this time.

5. ISSUES AND CONCERNS

- Current Pulsing. Accommodation of the SCRD requirements for current pulsing to each furnace module will require a detailed design analysis based on the specific sample properties and sample cartridge characteristics. This information was not available for the conceptual study detailed in this report.

- Safing Power. SSF requires that payloads be able to safe the system at all times. Since SSFF PCDS depends on both 6 kW buses for normal operations, loss of either bus would eliminate essentials power thus requiring initiation of safe shutdown. This could severely limit the operations of the SSFF if bus drop out is frequent.

- Electrical Isolation. The SSF requirement to provide 1 MΩ isolation between buses when tying them together impacts PCDS design. The current baseline addresses this by combining feeds in an essentials power supply. Each feed is connected to a DC-DC converter which electrically isolates the feed from the downstream side of the converter. The 2 outputs of the converters are electrically tied together to power DMS equipment required for safe shutdown. Pending results of analysis this may or may not be an acceptable approach for meeting the isolation requirement.

APPENDIX A
TRADES AND ANALYSES

APPENDIX A
TRADES AND ANALYSES

The PCDS Conceptual Design Report has highlighted the following areas where additional engineering trades and analysis are needed in order to obtain an optimum PCDS concept.

- Current Pulsing

  Detailed analysis required to identify a feasible concept which will meet the requirements listed in the Science Capabilities Requirements Document(SCRD) for SSFF current pulsing.

- Electrical Isolation

  Trade study required to identify most appropriate method of maintaining electrical isolation between SSF power buses(battery packs, transformer coupling, smart switching etc.)

- Switching Network

  Trade study required to compare the reconfigurable junction boxes to an active switching network. Although several disadvantages of an active switching network are obvious(requirement for 20 amp relays, EMI shielding requirements, additional software complexity for control) a more indepth trade study should be conducted to weigh the advantages and disadvantages of each design.

- Core Power Distributor

  Analysis to determine the feasibility of using SSF provide RPCMs vs. a SSFF designed distributor. Based on the current concept RPCMs will require a distribution box complement to provide all the required load switching for the PCDS. This analysis will determine if the distribution of power within SSFF can be accommodated more effectively with a SSFF designed box combining the functions of the RPCMs and the distribution box complement.

APPENDIX B
CORE POWER CONDITIONER CALCULATIONS

APPENDIX B
CORE POWER CONDITIONER CALCULATIONS

- Assumptions
    - Power modules rated at 100W each.
    - SSFF must have capability to drive furnace heaters to 100%.
    - Requirements based on Table 2-1.

- CGF

	MAX POWER	# MODULES REQUIRED
Hot Guard	250	3
Hot Main	900	9
Hot Main Redundant	900	9
Booster Heater	500	5
Cold Main	500	5
Cold Main Redundant	600	6
Cold Guard	250	3
TOTAL	3900	40

- PMZF

MAX POWER	# HEATERS	WATTS/HEATER	# MOD REQ'D
3000	32	94	32

- Total of 72 100W power modules needed.

APPENDIX C
POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM
COMPONENT SPECIFICATION SHEETS

Component Specification Sheet
SSFF PCDS-001-001 an 002

Assembly: Core Power Distributor
Component ID #: PCDS-001-001 and 002
Nomenclature: Remote Power Distribution Assembly (RPDA)
Description: These assemblies accomodate a Remote Power Controller Module which distributes 120 VDC power to SSFF equipment. The RPDAs & RPCMs are SSF provided. Each type V hybrid RPCM composed of 18 solid state power controllers(16, 3.5 amp switches and 2, 12 amp switches) controlled by a 1553 data bus. These controllers will switch power on/off to components upon receiving the appropriate command from DMS. One RPCM is connected to bus A and the other to bus B.
Qty. 2 RPDAs each accomodating a type V hybrid RPCM.

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 120 VDC
Power Delivered: Each RPCM will average a peak power delivery of 3 kW

Efficiency: Typically 99%.
Volume: .047 m3
Mass: 7.05 Kg

Component Specification Sheet
SSFF PCDS-001-003

Assembly: Core Power Distributor
Component ID #: PCDS-001-003
Nomenclature: Primary Distribution Box
Description: This box distributes 120 VDC power to the Core Power Conditioner Banks. The box is composed of 72 solid state power controllers. These controllers will switch power on/off to power modules upon receiving the appropriate command from DMS.

Qty. 1 Box composed of 72 power controllers

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 120 VDC
Power Delivered: Controllers will be required to deliver a maximum of 150W ea. at 120 VDC

Efficiency: Typically 99.5% base on component power requirements
Volume: .029 m3
Mass: 6.8 Kg

Component Specification Sheet
SSFF PCDS-001-004 and 005
SSFF PCDS-005-002 and 006-002
SSFF PCDS-007-001 and 008-001

Assembly: Various
Component ID #: PCDS-001-004/005, 005-002, 006-002, 007-001, 008-001
Nomenclature: Voltage/Current Sensor Package
Description: These sensors will be used to monitor power draw into the facility. A current and voltage sensor will monitor each feed into the RPCMs. Current and Voltage sensors residing in the furnace junction boxes will monitor power delivered to the furnaces. Sensors will monitor power fed into the Furnace power distributor.
Qty. 136 total sensors

Typical Characteristics
Input Voltage: ± 5 VDC
Output Voltage: ±5 VDC
Power Delivered: 0 (used for monitoring/control)

Efficiency: Typically 99.5%
Volume: Housed in existing PCDS assemblies.
Mass: Included in housing assembly.

Component Specification Sheet
SSFF PCDS-002-001 to 072

Assembly: Core Power Conditioner
Component ID #: PCDS-002-001 to 072
Nomenclature: Furnace Power Modules
Description: The furnace power modules take an input of 120 VDC and provide a variable voltage output to furnace heater elements. Modules are controlled by a trim signal from DMS. Modules will be configured in 2 CPC banks to allow maximum flexibility and configurability to a given furnace.

Qty. 72 modules in 2 banks

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 0-12 VDC
Power Delivered: 100 W per module max(200 W module derated 50% for flight qual)
Efficiency: 70% to 80%
Mass: 6 ounces each module, 47.2 Kg each bank.
Volume: 90.46 cm3 for each module. Each bank is .122 m3.

Component Specification Sheet
SSFF PCDS-003 and 004

Assembly: Core Junction Box A & B
Component ID #: PCDS-003 and 004
Nomenclature:
Description: Each junction box will take the inputs from the Core Power Conditioner banks and route them to the applicable furnace depending on its configuration. Typically 40 of the inputs will be routed to CGF while 32 inputs are routed to PMZF. These junction boxes will be reconfiguarble and easily accessable so that they may be replaced or reconfigured to meet additional furnace schemes. Each box will be fabricated in house.

Qty. 2 Boxes each composed of high power circuit boards and connectors suitable for routing the above stated inputs/outputs

Typical Characteristics
Input Voltage: 12 VDC max each module input
Output Voltage: 108 VDC max for 9 modules stacked
Power Delivered: 1333 W nominal, 4444 W max *
Efficiency: Effeciency for CJB is accounted for in line and connector loss calc assumed to be approximately 90% eff
Mass: 19.1 kg each
Volume: .004 m3 each

* Based on nominal CGF power of 900 w and max PMZF power of 3000 W plus losses for conversion of 75% eff and line loss of 90% eff

Component Specification Sheet
SSFF PCDS-005-001, 006-001

Assembly: Furnace Power Distributor 1 & 2
Component ID #: PCDS-005-001, 006-001
Nomenclature:
Description: This box distributes 120 VDC power to experiment rack equipment. The box is composed of 15 solid state power controllers. These controllers will switch power on/off to furnace rack components upon receiving the appropriate command from DMS. Will also be scarred for connection to SSF bus.

Qty. Ea. Box composed of 15 power controllers

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 120 VDC
Power Delivered: Each FPD will deleiver up to 6.19 A at 120 VDC (743 w max)

Efficiency: Typically 99.1% base on component power requirements
Volume: .004 m3
Mass: 7.25 Kg

Component Specification Sheet
SSFF PCDS-007 and 008

Assembly: Furnace Junction Box
Component ID #: PCDS-007 and 008
Nomenclature:
Description: These junction boxes will provide an interface to which the furnace power leads may connect. It will also provide housing for voltage and current sensors. Configuration dependent on furnace type. Each will be fabricated in house.
Qty. 1 Box in each furnace rack (total of 2) composed of connectors and terminal blocks.

Typical Characteristics
Input Voltage: each input will be variable VDC
Output Voltage: each output will be variable VDC
Power Delivered: CGF 900 W nominal, 2100 W max, PMZF 1200 W nominal, 3000 W max.
Efficiency: Effeciency is acounted for in line and connector loss calc assumed to be 90% eff
Mass: 9.6 kg each
Volume: .008 m3

Component Specification Sheet
SSFF PCDS-009 and 010

Assembly: Current Pulser
Component ID #: PCDS-009 and 010
Nomenclature:
Description: The current pulsers are of a TBD design. They consist of all the electronics neccessary to provide the current pulsing capabilities listed in the SCRD. Each box will be fabricated in house.

Qty. 1 Box in each furnace rack (total of 2)

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: TBD
Power Delivered: 40W time averaged.
Efficiency: TBD

Mass: TBD
Volume: .09 m3 (place holder).

Component Specification Sheet
SSFF PCDS-011, 012, 013

Assembly: Essentials Power Supply
Component ID #: PCDS-011, 012 and 013
Nomenclature:
Description: Each essentials power supply powers DMS components neccessary for safe shutdown of SSFF and any 28 VDC DMS components. Each supply is composed of 2, 120/28 VDC converters, each fed by an opposite SSF bus. These converters maintain the required electrical isolation betwen the buses. A third 120/28 VDC converter resides in each of the supplies in the experiment racks . This converter provides 28 VDC utility power for any experiment rack FPE.
Qty. 1 per rack

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 28 VDC
Power Delivered: core rack supply delivers 616 W max, each furnace supply 271 W max (excluding FPE)
Efficiency: 75%
Mass: 3.2 Kg each
Volume: .018 m3

SPACE STATION FURNACE FACILITY DATA MANAGEMENT SUBSYSTEM (SSFF DMS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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SPACE STATION FURNACE FACILITY DATA MANAGEMENT SUBSYSTEM (SSFF DMS) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

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EXECUTIVE SUMMARY

The Space Station Furnace Facility (SSFF) will be a payload for use on Space Station Freedom for the processing of metals in a microgravity environment. This will be to reduce the effects of convective flows around the hot/cold interface during processing of the material. It is hoped that this processing will produce more homogeneous crystallization of materials and samples that can reveal knowledge of the materials (that might not be able to be produced in a one gravity environment).

The SSFF will be a three rack facility for Space Station Freedom which will utilized for conducting experiments in the US-Lab module. The first rack (or Core Rack) will contain the general utilities needed by the furnaces for the processing of materials, such as: power switching and control; gas distribution; thermal dissipation control; and major SSFF DMS computer services (such as Space Station interface, data monitoring, processing, storage, and transmission). The other two experiment racks will contain the furnaces to be utilized in the facility, and will be setup so that either one or two experiment racks can be implemented (for a modular approach). These experiment racks will also contain the specialized monitoring/control units and the majority of the Mission Peculiar Equipment (MPE) needed by the furnaces.

The SSFF Data Management Subsystem (of which this concept report deals) is the portion of the design which will contain the electronics for control and monitoring of sub-systems associated with furnace operation such as: the Thermal Control System, the Power Distribution system, the Power Conditioning System, and the Gas Distribution System. In addition to these tasks, the system will also directly monitor the furnaces for ascertaining temperature via thermocouple inputs (and other sensors), control translation (i.e. movement of the relative sample position to the hot/cold zones), video camera position/focus and processing of video data, control other actuators/effectors for the furnace, provide a communications media for the facility, store digitized experiment and video data, and provide an interface to Space Station Freedom DMS.

In support of the Core rack, Experiment rack, Experiment rack concept, the SSFF will house most of the SSFF DMS equipment in the Core Facility. This core equipment will consist of the Core Control Unit (for the control, processing, and interfacing to SSF and SSFF DMS communications buses), the Core Monitor and Control Unit (for the monitoring and control of core Thermal Control System, Gas Distribution System, and Power Conditioning and Distribution components), the Video Processor (to acquire/digitize/ process video data), the Crew Interface Unit (for crew input and video display), and the High Density Recorder (which will store digitized experimental and video data). The Experiment racks will each contain a control system consisting of an Furnace Control Unit (FCU) and an Furnace Actuator Unit (FAU) which will monitor and collect data from the furnaces in each rack and provide control stimulus as needed for the

positioning of samples, and also for video camera control. In addition, core components from other SSFF subsystems will be monitored in each of the experiment rack by a Distributed Core Monitor Unit (DCMU).

This document details the conceptual design of the Space Station Furnace Facility Data Management Subsystem. This report includes a description of the requirements, an overall DMS concept, and descriptions of the individual DMS hardware and software components necessary to perform the SSFF DMS tasks. DMS configuration areas and components that require further analysis and/or trades to be performed are identified in Appendix A.

ABBREVIATIONS AND ACRONYMS

ACD	Architectural Control Drawings
BIT	Built In Test
CCU	Core Control Unit
CD/ROM	Compact Disk/Read Only Memory
CMCU	Core Monitor/Control Unit
CPC	Core Power Conditioners
CPU	Core Processor Unit
DMS	Data Management System
EDAC	Error Detection And Correction
EEPROM	Electrically Erasable Programmable Read Only Memory
ESA	European Space Agency
FAU	Furnace Actuator Unit
FBIU	Furnace Bus Interface Unit
FCU	Furnace Control Unit
FDACS	Furnace Data Acquisition and Control System
FDDI	Fiber Distributed Data Interface
GDS	Gas Distribution System
GSE	Ground Support Equipment
HDR	High Density Recorder
HRDL	High Rate Data Link
HRDM	High Rate Data Multiplexer
HRL	High Rate Link
I/O	Input/Output
IRD	Interface Requirements Document
LAN	Local Area Network
MPE	Mission Peculiar Equipment
MSU	Mass Storage Unit
mux/demux	Multiplexer/Demultiplexer
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NTSC	National Television Standard Code
PCS	Power Conditioning System
PCDS	Power Conditioning and Distribution System
PDS	Power Distribution System
PDR	Preliminary Design Review
QWERTY	Standard Keyboard
RAM	Random Access Memory
RHD	Removable Hard Drive
RTD	Resistive Thermal Device
SCRD	Science Capabilities Requirements Document
SCSI	Small Computer Serial Interface
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To Be Determined
TCS	Thermal Control System
TDRSS	Telemetry Data Relay Satellite System
VGA	Video Graphics Array
WORM	Write Once Read Many

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The scope and purpose of this report is to present the Space Station Furnace Facility Data Management Sub-System (SSFF DMS) requirements, and the baseline design concept developed that meets those requirements. The report includes a description of the requirements, an overall DMS concept, and descriptions of the individual DMS hardware and software components necessary to perform the SSFF DMS tasks. DMS configuration areas and components that require further analysis and/or trades to be performed are identified in Appendix A.

The task of requirements definition and design concept development was performed by the Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration (NASA).

1.2 GROUNDRULES & ASSUMPTIONS

The following is a list of groundrules and assumptions that were used in the concept development of the SSFF DMS.

1. The DMS interface to the Space Station Freedom (SSF) will be based on DMS Architectural Control Drawing (ACD) Revision D dated July 1,1991 and the Payload Interface Requirements Document (IRD).
2. To the extent possible Mission Peculiar Equipment (MPE) will be located in the furnace rack portion of the Furnace Facilities.
3. Assume reasonable access to the SSF and to the Telemetry Data Relay Satellite System (TDRSS) Ku-Band by the Payloads
4. Assume transmission of high resolution video can be up to 5 minutes an orbit, rate not to exceed 43 Megabits per second including overhead.
5. Video frame rate and resolution will be limited such that the data generation without compression does not exceed 1300 Megabits per orbit.

2. DMS REQUIREMENTS

2.1 GENERAL DMS REQUIREMENTS

The SSFF DMS will meet the requirements identified in documents DR-7, Function and Performance Specifications for Space Station Furnace Facility, the SSFF Capability Requirements Document, and those requirements derived from analysis of the SSFF operations and furnace facility mission sets.

These requirements include the following functions: monitor and control of SSFF subsystems and furnace facilities; performance of Built-In-Test (BIT); data monitoring/processing/ storage and retrieval; interface to the SSFF DMS functions, subsystems, and services; human interfaces (keyboard and display); Ground Support Equipment (GSE) interfaces; and video acquisition, distribution, and processing.

2.2 DMS INTERFACE REQUIREMENTS

This section details the different interface requirements that the SSFF DMS must service. Figure 2.2-1 shows these interfaces.

2.2.1 SSF Interfaces

The SSFF DMS will provide the capabilities to interface to the SSF for commands/services and transmission of data to ground. The link will be compatible with either the SSF MIL-STD-1553 BUS or the payload Fiber Distributed Data Interface (FDDI). These interfaces will conform to SSF protocols (as serviced by SDP-7) for compatability with Space Station Freedom standards.

The SSFF DMS will provide a HRDL interface to the SSF patch panel to accommodate transfer of high rate data up to 43 Mbits/sec (as allowed by the maximum usable bandwidth of the TRDSS downlink). This interface will be the primary method for the transmission of collected data (by the SSFF) to the Ground. The HRDL interface will be as specified by the Space Station Freedom Document SSP XXXXXXX which will allocate a specified amount (TBD) of the available bandwidth of the TDRSS downlink to the SSFF. It is understood that if the SSFF is not transmitting data, it will be required to conform to HRDL protocols and support the HRDL format as necessary (such as the inclusion of "filler" bits into the data stream).

The DMS will provide a video system interface to transmit SSFF experimental data to Space Station Freedom via the SSF HRDL or SSF Video Services (in analog NTSC format) Interface for use aboard Space Station Freedom, or for digitization and transmission to Ground by Space Station Freedom Video Services.

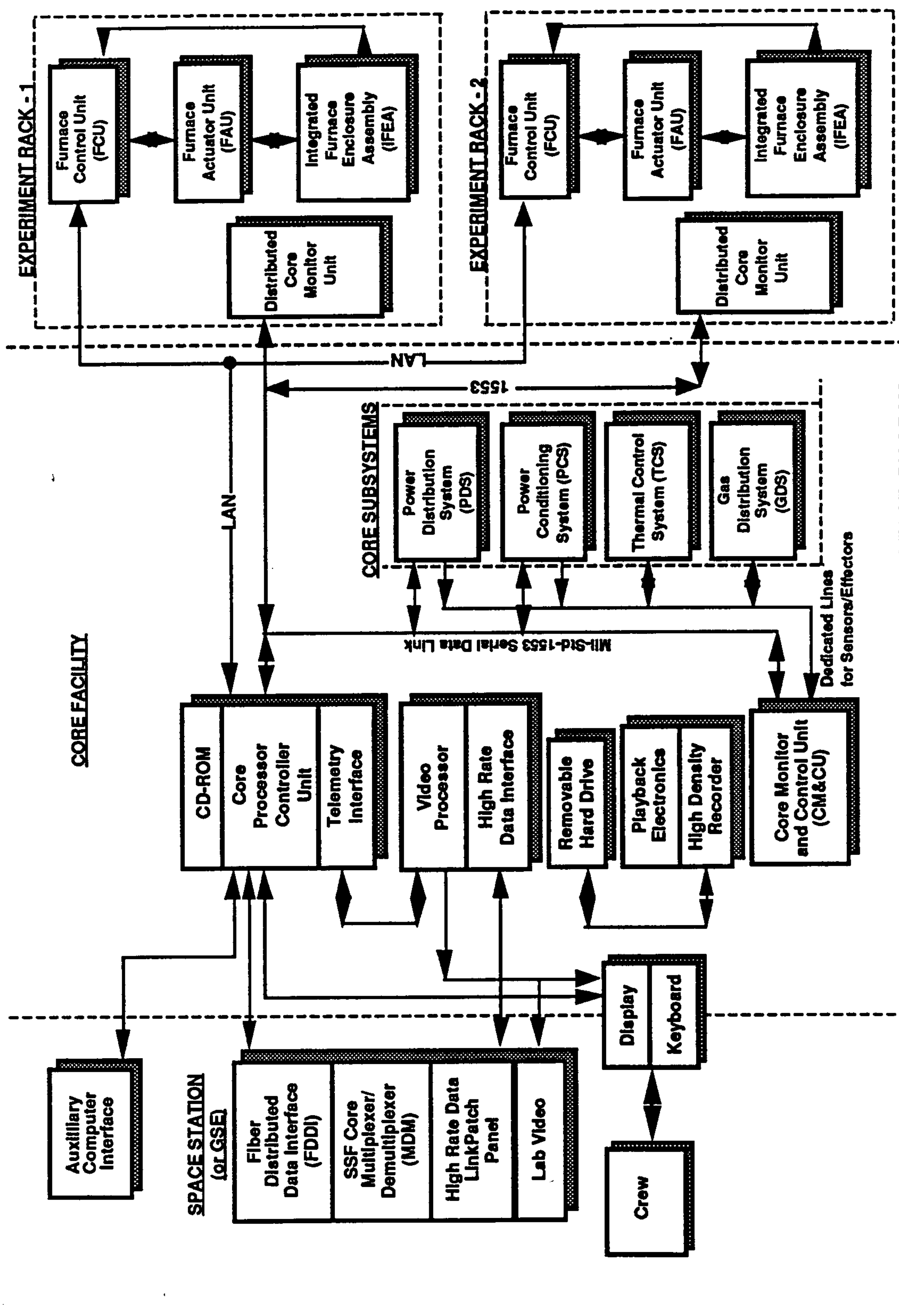


FIGURE 2.2-1. SSFF-DMS INTERFACE DIAGRAM

2.2.2 SSFF DMS Experiment Module Interface

The SSFF experiment modules will be serviced by a series of DMS components. These components will be made up of a Furnace Control Unit (FCU), Furnace Actuator Unit (FAU), and the Distributed Core Monitor Unit (DCMU). These units will perform the following functions: FCU will perform the acquisition and processing for the sub-system; the FAU will provide stimulus to the experiment module as necessary; and the DCMU will monitor the Distributed Core Components in the experiment rack and a limited number of safety sensors in the rack. The FCU and FAU will be modular and reconfigurable to meet the varied needs of different types of furnaces, where the DCMU is designed to meet the needs of different types of experiment racks through a series of standard sensors.

The SSFF DMS will provide a video data acquisition and control interface to furnace module provided cameras. This system will be capable of acquiring video data, performing frame grabbing, processing, and interfacing to a High Density Recorder (Digital). The analog section of the video collection will be based around the NTSC and RGB formats.

2.2.3 SSFF DMS Subsystem Interface

The SSFF DMS will provide an internal Data Management Sub-Systems communications interface for intercommunication between the components of the SSFF DMS. This system will provide a means for communicating command, control, and status data between the components and also between the Core and Experiment Racks. The system will also allow for the transmission of programming data for the reconfiguration of the higher levels of software controlled parameters.

2.2.4 Crew Interface

A keyboard and display interface will be provided, as part of the core facility, for crew interaction. This system will have a standard QWERTY type keyboard which can accept crew input commands for operation or configuration of the SSFF subsystems as required. The keyboard will be a ruggedized unit with tactile and audible feedback for reliable crew operation.

The Display will provide for the viewing of tabular data relaying status on furnace operations as well as facility status. The display is capable of also displaying color video collected by the Video Processor. The display has a resolution of TBD vertical by TBD Horizontal picture elements (or pixels).

2.2.5 GSE Interface

The SSFF DMS will provide an interface to Ground Support Equipment (GSE) to support ground checkout. This interface allows the connection of diagnostic and checkout of the DMS subsystem independent of the Space Station Freedom Data Management System. These interfaces will be composed of bidirectional serial communications ports (and discrete input/output lines) for

the commanding and monitoring Space Station Furnace Facility components. In addition, these interfaces will be capable of placing the SSFF DMS components into Built-In-Test (BIT) and alternate diagnostic modes.

The primary use for GSE will be in the substitution of GSE for the standard DMS interfaces. This will enable the GSE to take the place of the Space Station Freedom systems that would normally be used for the commanding of the Facility for test and checkout purposes.

3. CONCEPT DESIGN DESCRIPTION

3.1 TRADES AND OPTIONS

In the formation of the Space Station Furnace Facility conceptual design, several different trade studies were undertaken to optimize the system architecture and components. This section details those studies and gives the results.

3.1.1 Distributed vs. Centralized

This trade study deals with the concept of centralization vs. decentralization of processing power and control for the SSFF design. The items reviewed for the study included such aspects as ease of maintenance/upgrade, safety (redundancy/qualification), reliability, volume (inter-rack cabling as well as inner-rack cabling), reconfigurability, software impacts, hardware designs, architectural considerations, data bottlenecks (control considerations), and configuration/ qualification control. The three major designs philosophies were of a Centralized System, a Totally Distributed system, and of a Hybrid system which incorporated the better features of both systems.

3.1.1.1 Centralized - The centralized system has some obvious advantages with centralization of all aspects of the facility. However, with this centralized concept comes several problems. The mechanical aspects of the system become difficult, since all data from both the experiments and the core subsystem components (TCS, GDS, PDS) must all funnel to the same point, making the interconnection difficult at best. Modularity and upgrade suffer since any changes impact the entire facility as a whole. Software suffers the same problem with having many tasks (both Experiment and Facility support software having to be interleaved in the real time domain) this causes many problems from a configuration management standpoint and curtails the upgradability/modifiability of the system. This concept is illustrated by Figure 3.1.1.1-1.

3.1.1.2 Distributed - The Distributed concept works well in concept, but from a practical standpoint it has some problems. Experimental work (especially in a laboratory designed for specific types of experiments such as materials processing) has many common functions. In the Space Station Freedom environment, this involves interface to SSF resources, control of Space Station Furnace Facility resources, data logging, reconfiguration, and data processing. The totally distributed concept would have to have all of these tasks duplicated in each experiment rack thereby essentially having multiple copies of the centralized control concept. This would be unacceptable since it takes the short-comings of the Centralized approach and adds multiple sets of hardware for each of the experiment racks. This means that each rack will have less space devoted to the experiment it is intended to house, and more to dealing with SSF, managing its' own resources, and control of its experimental tasks.

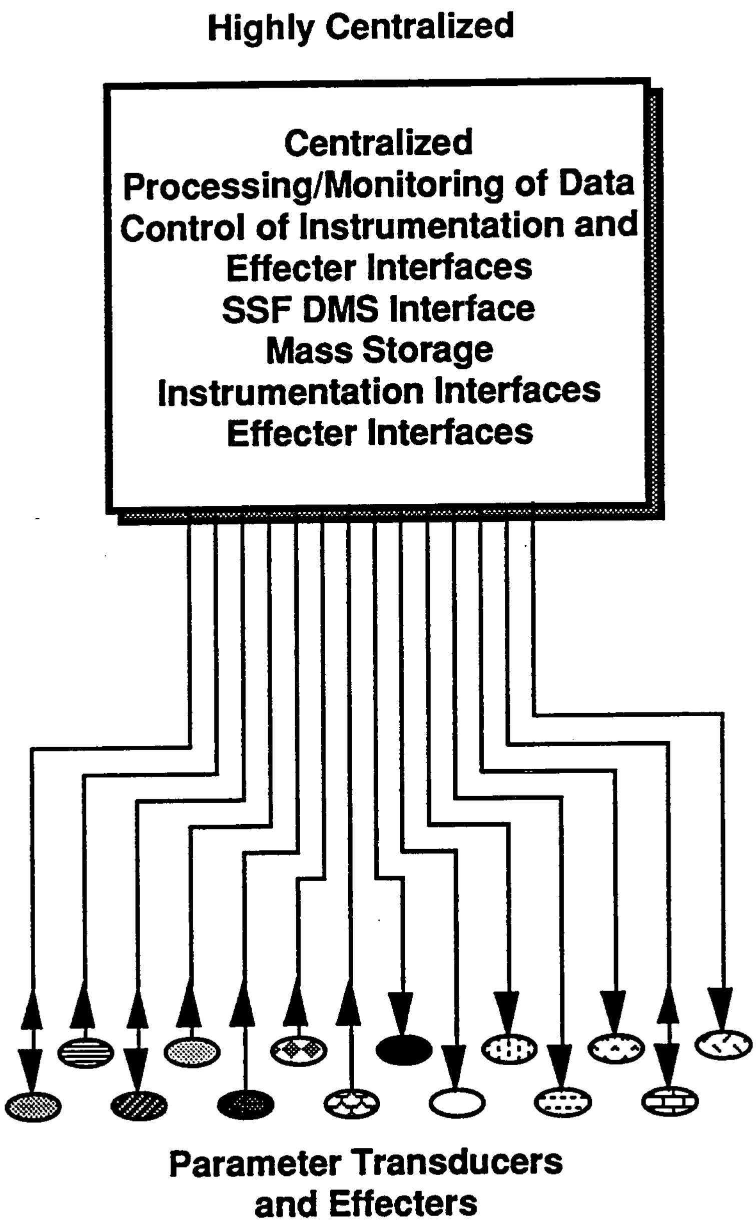


FIGURE 3.1.1.1-1
CENTRALIZED CONTROL AND MONITORING

3.1.1.3 <u>Hybrid System</u> - The next system to be reviewed is the hybrid concept, part centralized, part distributed. It can be readily seen that in any experimental facility there are two tasks to be performed: first, dealing with the control and operation of the facility; and the second, with the operation of the experiment. In both of these tasks, there will be common tasks that must be performed, as well as specialized tasks (whether by task or by location of the task). The common tasks would be interface with the operator (i.e. SSF), data storage, reconfiguration, data processing, and resource management (power, gases, cooling), whereas the specific tasks would be data acquisition (experiment dependent and location dependent (due to mechanical constraints)) and control (with the same considerations as acquisition).

It was found that many of the common tasks lent themselves readily to be incorporated in the Core Facility (SSF Interface, high-level experiment control, facility control, data storage, reprogramming), and others (such as Experiment control and data acquisition (Experiment and Core)) lent themselves to being placed in remote units. In some cases this decentralization was to ease the mechanical and inter-rack wiring of the facility, and in all instances it helped with the flexibility and modularity for ORU change-out and upgrade capabilities.

As a result of surveying the different software tasks and how they must be performed, it became obvious that certain control tasks lent themselves to being out by the experiment, and other higher level tasks needed to reside in a Core computer. It also became necessary for the easing the software complexity and qualification, to separate out the Core (or Facility tasks such as Safety) from the experimental tasks. This will allow the independent qualification of Experimental software from Core software, thus lessening the burden on the Experiment Developer for qualification. This was possible since an independent system in the SSFF will be handling the safety and redundancy aspects of control for the facility. These control aspects deal with the bottlenecks that form at major data intersections, where many items are dealing with a common resource (whether that resource be a processor, or a data links' throughput capacity, is really immaterial).

Figures 3.1.1.3-1 and 3.1.1.3-2 illustrate the decreasing bottleneck that results from different degrees of decentralized processing ability, data acquisition, and control. This gives an idea of the advantages of decentralization of processing power. As processing power moves toward the acquisition system, bus bandwidth requirements decrease, and turnaround time in the control loop also decreases. This has some advantages in a real-time control system, from a control standpoint, as well as a redundancy and cross-checking standpoint. The more processing power that is placed in a system, the more redundancy can be implemented (with minimal impact to the system operation). For instance, it would be entirely possible for one processor to check on another (as long as redundant sensors are incorporated in the design. It would also be possible for one processor to engage a safing procedure in the event of problems with the primary processor.

Decentralized I/O

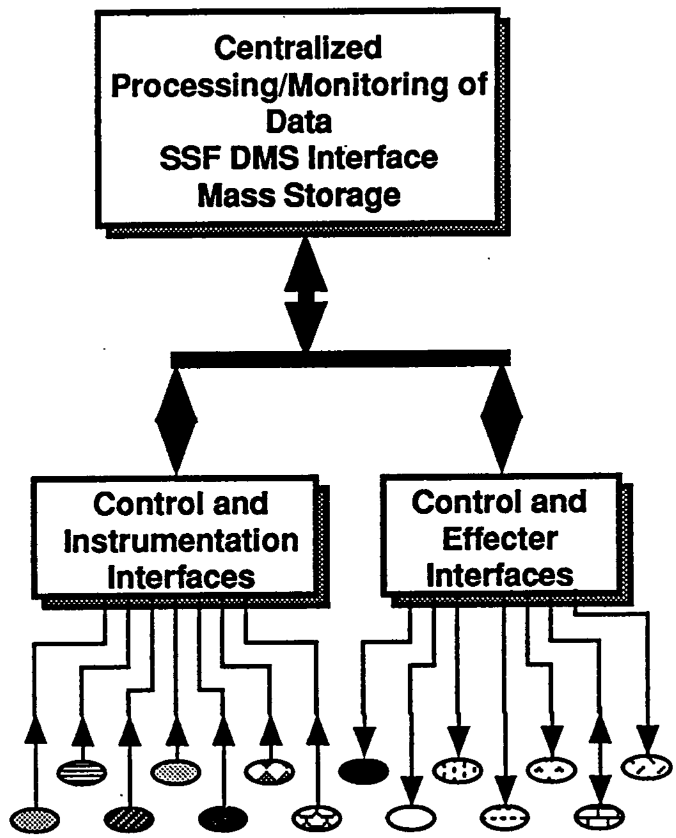


FIGURE 3.1.1.3-1
INTERFACE ONLY
DECENTRALIZATION

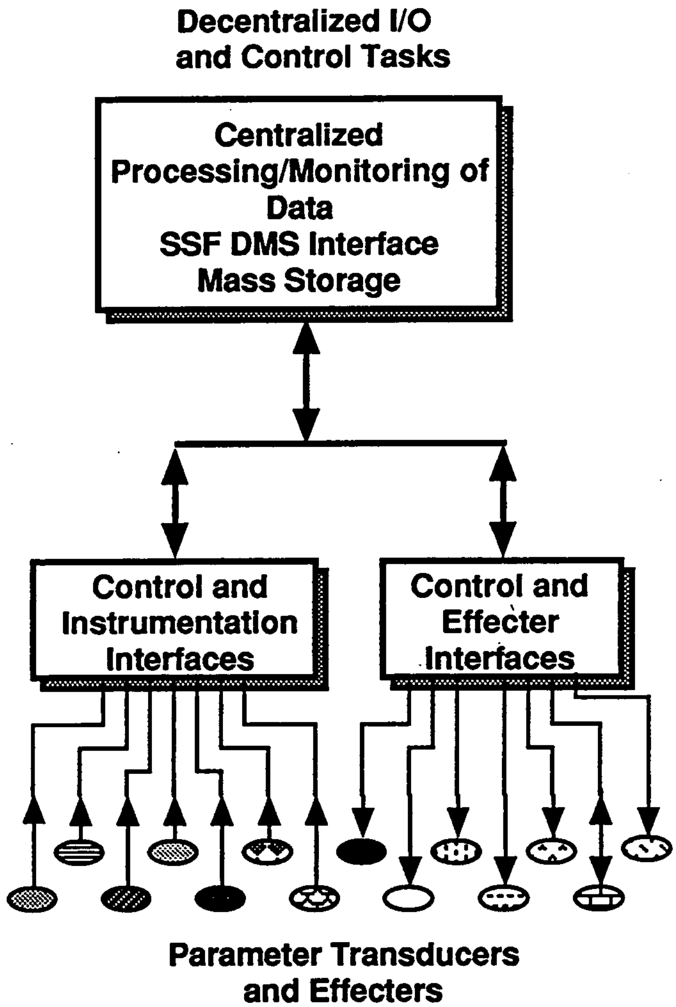


FIGURE 3.1.1.3-2
PROCESSING AND INTERFACE DECENTRALIZATION

Results:

- Decentralization of Processing and Interfaces yields:
  - Flexibility (Modularity)
  - Facilitates On-Orbit Change-out (Orbital Replacement Units)
  - Ease of upgrade at a later time
  - Better accuracy due to lead lengths (fewer EMI/EMC Problems)
  - Simplification of mechanical (wiring) and software interleaving of tasks) design
  - Safety Factors (Redundancy and Separation of Experiment and Facility Operations)
  - Ease of software and hardware development

3.1.2 Storage of Experiment Data

This trade study reviews technologies available for high density recording of data. Of the different technologies available for the high density storage of data, only two (Optical and Magnetic Tape) had densities near the requirements for MTC storage of APCGF data. Others disqualified themselves because although they were dense, at the higher capacities they became cost prohibitive. Since experimental data is logged sequentially, the tape technology qualified as a possibility, since random access is not necessarily a requirement. Capacity of several hundred GigaBytes was a minimum requirement.

Several tape drives were available from many manufacturers since this is a very mature technology, and a wide selection of data recorders are available for military as well as space qualification standards.

Optical Recorders are a very new technology, and few military and even less space programs have these available to them at present. Optical Tape might be viable in the future with a higher capacity than any of the others; however, it is an even less mature technology with commercial units just starting to make an appearance in the marketplace.

Power	Volume	Capacity	Recommendation	
Magnetic Tape	200 watts	4 cubic ft	1.88 Tbit max	Previously flown 1st
Optical Disk	1Kw	1 SSF Rack	2 Tbit max	under development
Optical Tape	N/A	N/A	1Terabyte	under development

At the present time it appears that tape is the logical to way to go. Space Station Freedom and SpaceLab are also conducting reviews of technology at the present, and have also come to the same conclusion: tape (for the time being) is the most economical power, volume, and capacity wise.

3.1.3 Reprogramming

The following list reviews some of the technologies available for reprogramming and makes a recommendation for the technology to be used for reprogramming the APCGF CDMS.

Recommendations	Random Access	Storage Capacity	Constraints
EEPROM Cartridge	Yes	up to 100 MB	Density-1st Previously Flown
Magneto-Optical	Yes	up to 500 MB	new technology-2nd Recommendation Mechanical
Hard Drive	Yes	up to 200 MB	Mechanical
Magnetic Tape	No	up to 2 GB	Mechanical Access Time
Floppy Disk	Yes	up to 1 MB	Mechanical Rigidity of media
Battery Backed-Up RAM	Yes	up to 100 MB	Problems with Space Qual.

EEPROM Cartridge technology has been successfully flown on several Space Lab missions and is currently being used by NASA Lewis on several programs. It excels in density, power, amount support circuitry required (minimal), access time, random access, and no moving parts in contact with the media. Current capacities are about 40 Megabytes with 100 Megabytes being planned. The only drawback is the number of write cycles for the media (typically 10000), which does not hold any problems for SSFF utilization since SSFF needs a minimum number number of write cycles to this media. The magneto-optical is a young technology with little in the way of even military hardware available, and still requires a mechanical system (produces vibration). The different types of magnetic media have flown before; however, they do involve contact with the media in tape and floppy disks (disk drives use the Winchester effect to levitate the head assembly over the media), and a mechanical system for reading the media in all the systems. Finally, where RAM cartridges have the same advantages as the EEPROM Cartridge, they do require constant power to maintain storage of their data, thereby requiring batteries which are difficult to qualify for a manned environment.

As can be seen, for the needs of reprogramming the facility, the EEPROM cartridge is the most attractive at present. As technology changes, there is a possibility of other technologies being more attractive, but for the time being, the best is the EEPROM cartridge.

3.2 SELECTED CONCEPT

The following system description reflects the results of the previous sections trade studies: Hybrid Distributed over Centralized; Tape as a form of Mass Storage; and EEPROM Cartridge for

C-2

storage of reprogramming data. It should be noted that the most significant was the result of the Distributed over Centralized which resulted in a hybrid architecture, since this has brought the Mass Storage and Reprogramming capabilities into a centralized location in the Core Facility, as will be discussed in the following paragraphs.

This hybridized distributed/centralized concept has separated the control over the facility as a whole into two major categories:

1. Core Tasks (or Functions) - dealing with the overall management of resources and facility control.
   a. Overhead Control/Interface.
   b. Sensor Specific Interface.
   c. Location Specific Interfaces.
2. Experiment Tasks (or Functions) - dealing with the management of experiment resources, observation, and control.
   a. Overhead (Common) tasks.
   b. Experiment (or Sample Specific) tasks.

As a result of these different types of tasks, many of the common tasks will be centralized, and others will be delegated to monitoring and local control out at the experiment racks. In some cases, to eliminate the logistics of wiring a whole series of sensors and effectors to a central location, it will be simpler to have an interface which samples the signal (or controls and monitors) at the necessary rate, and multiplexes the monitoring and control data over a common serial data bus. This will reduce the mechanical complexity of the SSFF DMS implementation, and also will help the routing of wiring between racks.

It can be seen that from a control standpoint (especially from the software standpoint), it makes sense to separate the two systems (Core and Experiment). This approach will make the code easier since it will not have to be interleaved between the Experiment and the Core, and also will have the added benefit of making the software easier to qualify, since the safety controls will be separated out into a redundant system.

In this concept, there is of course one place where the data must come together. The Core Control Unit will be that central node, and will be the central processing point where both of these systems join for orchestration and collection of data for processing, control, storage, and/or downlink. The other subunits/sub-processor/controllers will fan out from this point to yield effective control of the facility. This will be discussed further in the following sections.

3.2.1 CONCEPT DESCRIPTION

The decentralized concept that was arrived at was one of not only decentralization for the Experiment DMS system, but also, to reduce the amount of wiring and complexity,

decentralization for the control of the Core subsystem components (TCS, PDS, and GDS). As a result there are two separate systems involved in the performance of the experiments: the Furnace DMS, which will be primarily concerned with experiment data and control thereof; and the Core DMS system, which will be more concerned with the safety and general operation of the sub-system.

3.2.1.1 Furnace DMS Design - The Furnace DMS DMS (shown in Figure 3.2.1.1-1) will be the primary control and data link between the core facility and the furnace facilities. All control, status, and data to and from the furnaces will be transmitted on this medium.

The interface structure will be one of a dual redundant serial communications Local Area Network (LAN) with an auxiliary channel that is used for redundancy purposes. This redundancy will add a safety element which insures that one failure will not bring down the entire communications system. This will provide a safe and reliable means for communication between the SSFF DMS components. This interface design (called the Furnace Bus Interface Unit (FBIU)) will interface the CCU to the physical media (wire), and interface the FCUs in the Experiment Racks to the same media. This interface will be a memory mapped interface which will allow operation independently of the processor or microcontroller. Data will be simply written into a local memory (that is part of the interface itself) by the processor for transfer to the DMS, so that the operation of the processor or microcontroller can proceed with a minimum of impact. The FBIU also will have a microcontroller built into the design to supervise the task of data handling to and from the memory, and to ease to task of interfacing to the Furnace DMS Bus.

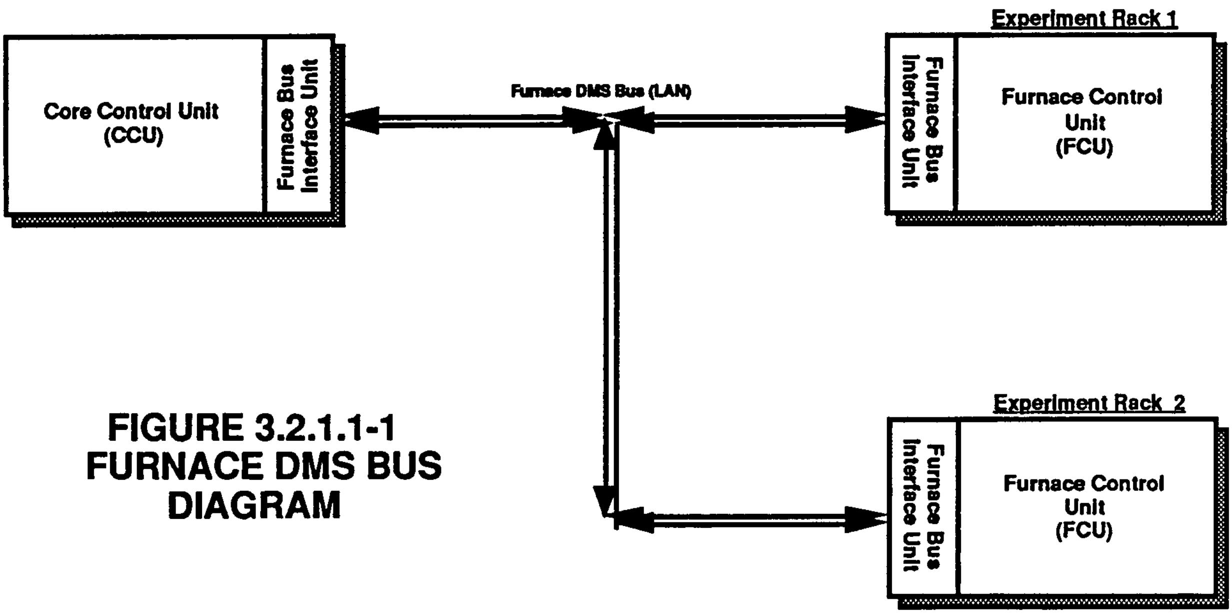


FIGURE 3.2.1.1-1
FURNACE DMS BUS DIAGRAM

The Furnace Control Units will be resident on the bus as Remote Stations. The Bus will be structured as a party-line organization with each master or slave having its own peculiar address. This will allow any station to communicate with any other station, or through the use of a broadcast command, to all units on the bus simultaneously. The Bus Station #1 (contained in the CCU) will serve as a traffic controller/monitor to insure that all communications are properly validated and distributed between the different subsystems. The distributed intelligence of the subsystems will make this easy since the majority of the traffic flow will be data coming to and from the core facility itself, with the Core Control Unit initiating actions and monitoring the resulting data.

3.2.1.2 Core DMS Bus (MIL-STD-1553) - The Core DMS Bus (shown in Figure 3.2.1.2-1) will be the control and data link between the Core Control Unit and the various units involved in monitoring and controlling the Thermal Control Sub-Systems, Power Distribution Sub-Systems, and Gas Distribution Sub-Systems either in the Core Rack or out in the experiment racks. Control, status, and data to and from the sub-systems will be transmitted on this medium.

The interface structure will be one of a dual redundant MIL-STD-1553B link. The redundancy will add a safety element which insures that one failure will not bring down the entire communications system. This will provide a safe and reliable means to communicate with the other portions of the system. The CCU will be able to safely and reliably communicate with the DMS Components. This interface design (MIL-STD-1553) will be contained in the CCU, the Core Monitor and Control Unit (CMCU), the PDS Remote Power Control Modules (RPCMs), the PDS Core Power Conditioner Stimulus, Power Distributor, and the Distributed Core Monitor Units (DCMUs) which will reside in the Experiment Racks. This interface will be a memory mapped interface which allows operation without a great deal of intercession on behalf of the Processor/Controller (or in any of the other units in which this interface resides). This interface will be implemented in a standard chip set available from several manufacturers (including the suppliers of Space Station Freedom DMS 1553).

Each of the DMS Components will be configured as remote terminals on this bus with separate addressing for each of the remote terminals. In the event of an emergency, it is possible (through Dynamic Bus Control (MIL-STD-1553B Spec.)) for one of the Remote terminals to act as a backup Bus Controller to safe the system. This will allow for a safe shutdown of the SSFF, in case of problems with the CCU. An additional safe guard will be added in the form of a differential safety line which any of the units on the bus can command in case of the suspected failure of another unit (i.e. if that unit continues to not respond to continued requests). This line will cause the relinquishing of control by the current Bus Controller and the assumption of Bus Control by the secondary unit.

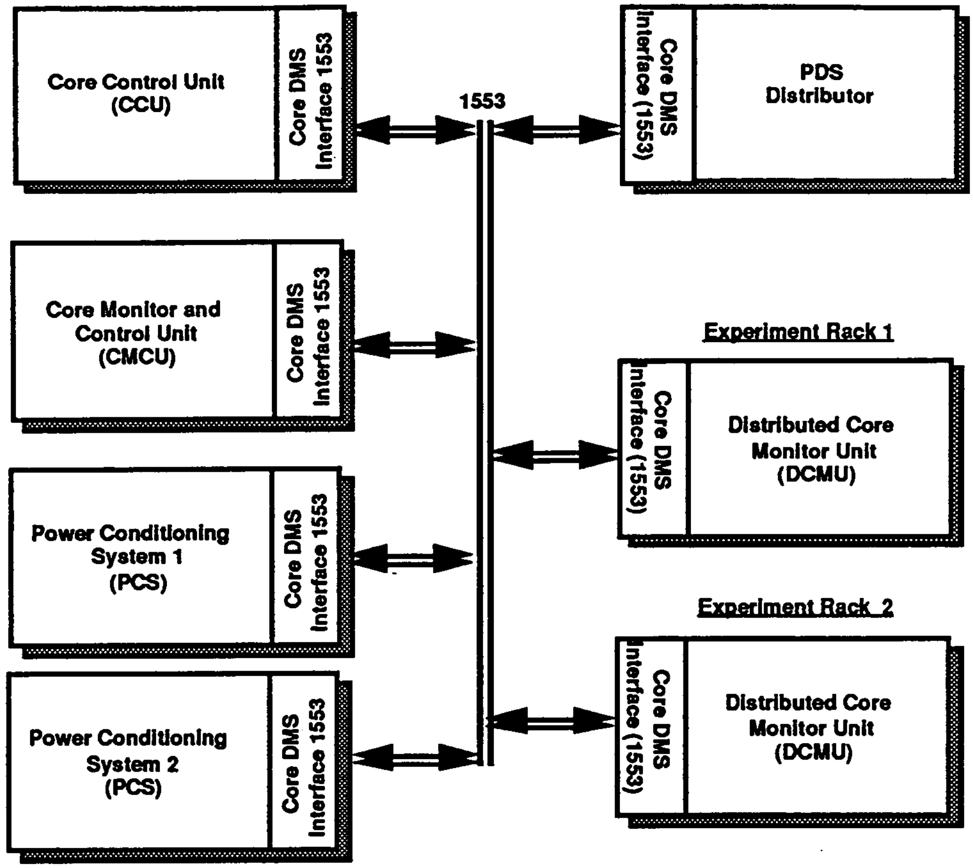


FIGURE 3.2.1.2-1
CORE DMS BUS DIAGRAM
(MIL-STD-1553)

3.2.2 COMPONENT DESCRIPTION

The SSFF DMS will be a distributed sub-system consisting of a Core Facility DMS subset and two Experiment Instrumentation subsets (one for each furnace rack) that reside in the core and furnace racks respectively. The core facility DMS will be a set of common equipment that is designed to serve as the top level SSFF controller and provide standard housekeeping services to the SSFF DMS modules which include; inter-subsystem communications, control, configuration, programming, and monitoring. The furnace facility DMS will provide local control/monitoring and those support functions that are unique to the particular furnaces such as furnace translation rates and temperature profiles. These facilities will be interconnected by a local bus (LAN) to accommodate the high level control and monitoring of the furnaces by the Core Control Unit. In addition to normal services, the SSFF DMS will also provide (in the core DMS) provisions for handling high bit rate (>10 Megabits) and video acquisition/processing. The distributed core subsystem components (PDS, GDS, and TCS) in the Experiment Racks will also be monitored by the Distributed Core Monitor Units which are connected to the Core Facility via a MIL-STD-1553

Bus. The SSFF DMS Hierarchy diagram is shown in Figure 3.2.2-1, and the Block Diagram in 3.2.2-2.

3.2.2.1 <u>CORE FACILITY DMS</u> - The Core Facility DMS components will be located in the core facility rack and consist of the Core Control Unit (CCU), the High Density Recorder (HDR), and a Video Processor. The Core Facility DMS components will provide the top level SSFF control and provides interface and communications to the furnaces, Space Station Freedom DMS, Station Crew, and Ground Controllers. The Video Processor will be a mission peculiar item and will be an exception to the groundrule that MPE must reside in the furnace racks. The subsystem configuration can be seen in Figure 3.2.2.1-1, and for views of the components, please refer to the corresponding section.

3.2.2.1.1 <u>Core Control Unit</u> - The Core Control Unit (CCU - SSFF DMS-CCU-001) will consist of the Core Processor/Controller, a removable ruggedized hard drive, a Reprogramming Unit, Core Monitor and Control Unit, a Network Interface Unit (NIU), a Furnace Bus Interface Unit (FBIU), and a Crew Interface Computer which will allow display and input of data (similar to a GRiD). These are discussed in the following paragraphs, and the Core Control Unit is shown in in Figures 3.2.2.1.1-1 - Isometric Diagram, 3.2.1.1.1-2 Functional Block Diagram.

3.2.2.1.1.1 <u>Core Processor/Controller (and Processor Memory)</u> - The Core Processor/ Controller (shown in Figure 3.2.2.1.1.1-1) will be the top level controller and interface device for the SSFF. The Core Processor/Controller will be powered up by the SSF which in turn will activate and configure each of the core and furnace facility components/sub-systems in accordance with the selected SSFF operational scenario(s). The Core Processor/Controller will monitor the furnaces (via the FCU/FAU) during operation of the facility, and monitor the other Core Facility Sub-Systems via the Core Monitor and Control Unit and Distributed Core Monitor Unit (DCMU).

The Core Control Unit Core Processor/Controller will be the central processor for the DMS that will direct the operation of the I/O Cards and subcomponents contained in the CCU. It will consist of a 80C386/486 Processor (or equivalent, along with a Math Co-Processor) which will be capable of processing the data received from the I/Os, sending data to the high density recorder, the SSF DMS for display and/or downlink, or to the CCU Video Display Unit.

The memory associated with the Core Processor/Controller will consist of TBD Megabytes of Static RAM and TBD Megabytes of EEPROM. The operational software for initialization and baseline configuration will be stored in (and operate out of) EEPROM. This operational program, when initialized, will request that data be transferred from the Reprogramming Unit (EEPROM Cartridge) so that specialized operational parameters and procedures can be utilized for experimental scenario to be performed with a particular furnace (or experiment).

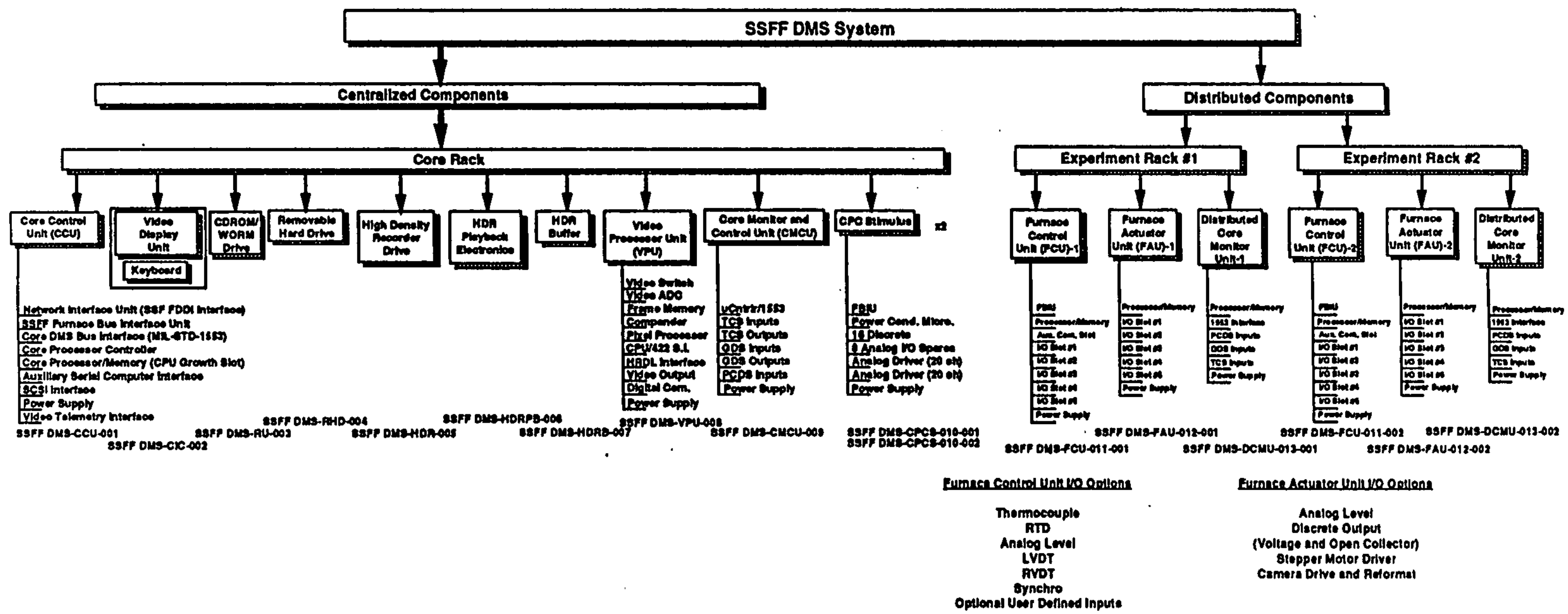


FIGURE 3.2.2-1
COMPONENT TREE DIAGRAM

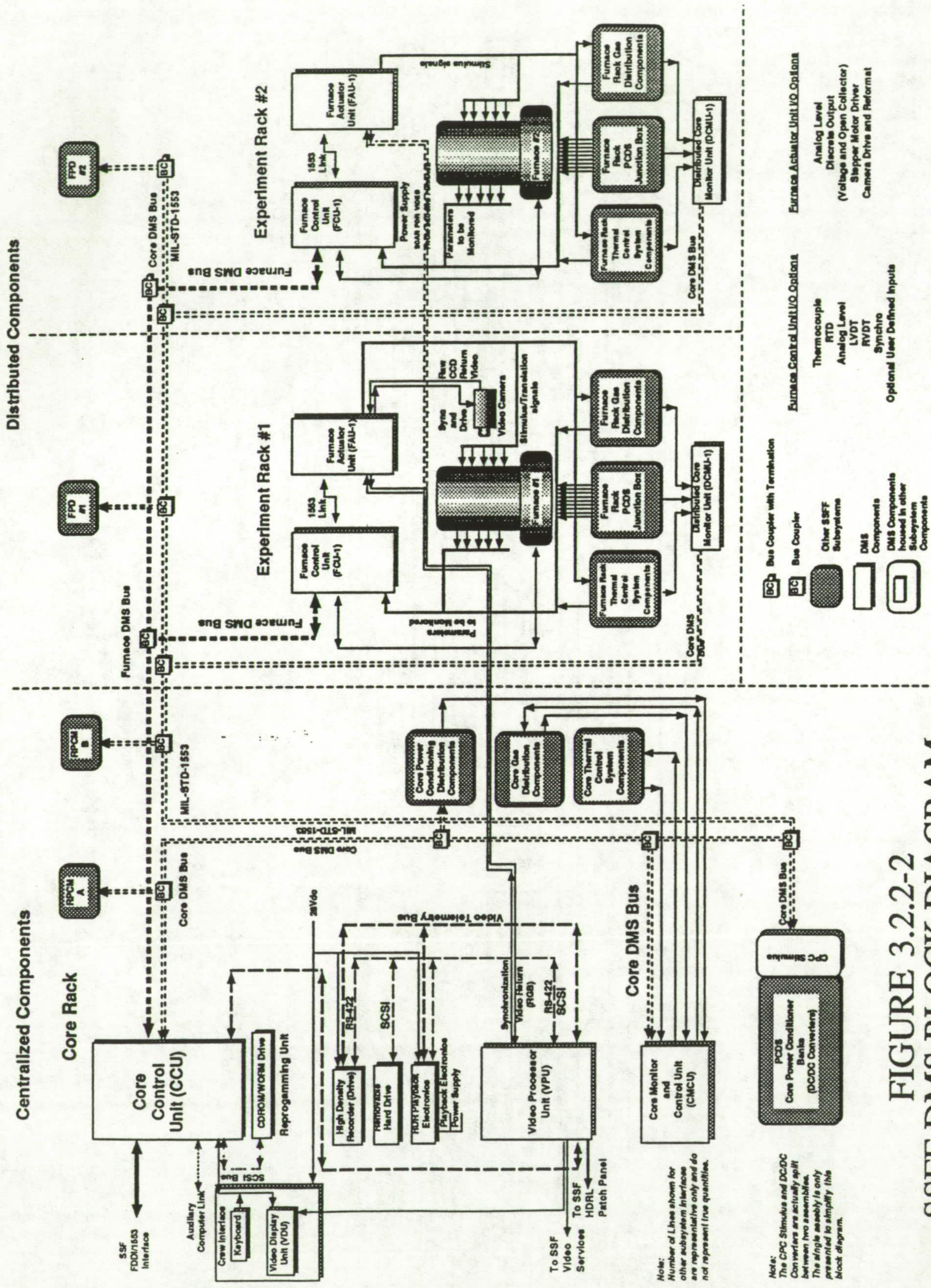


FIGURE 3.2.2-2
SSFF DMS BLOCK DIAGRAM

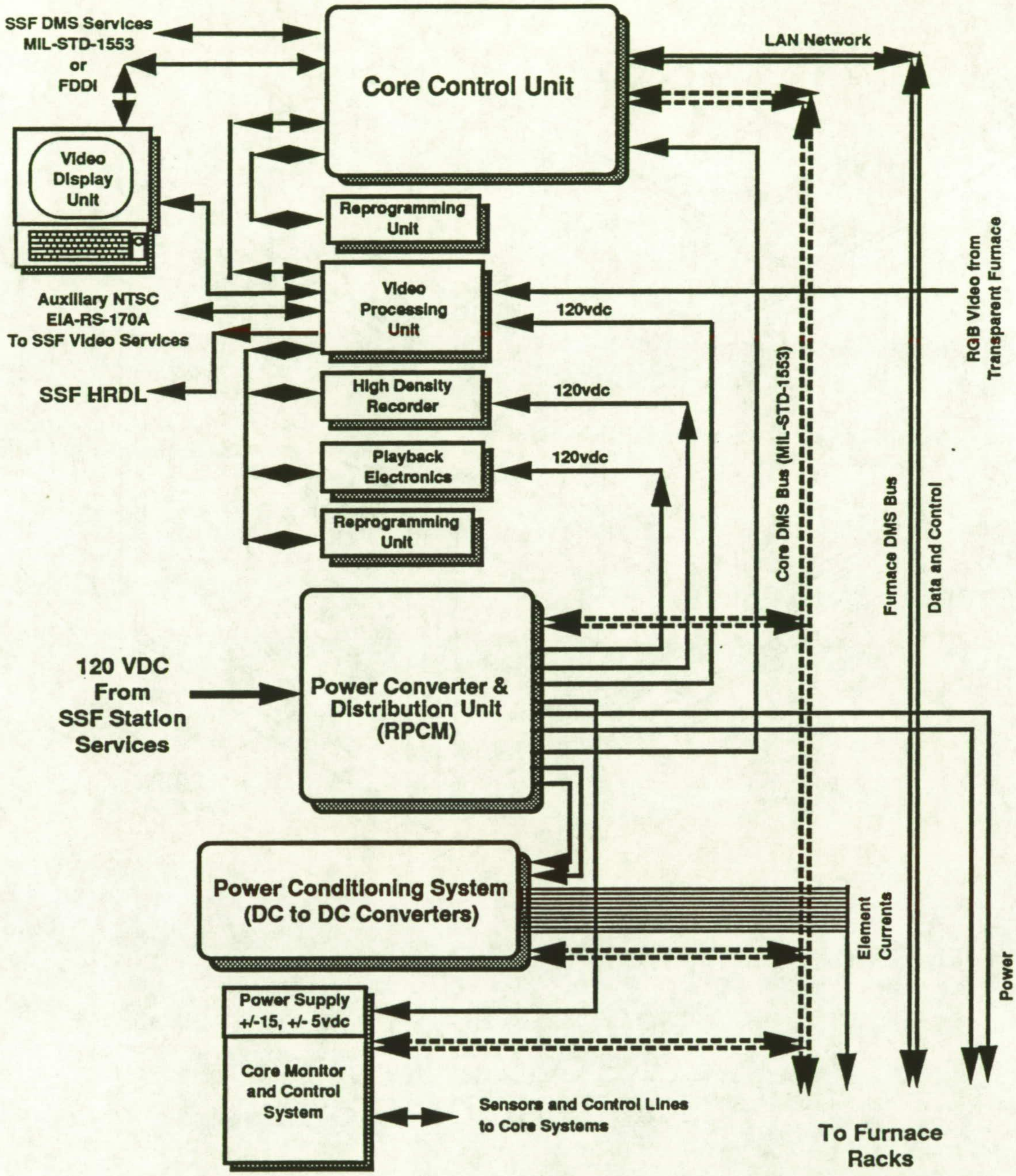


FIGURE 3.2.2.1-1 - SSFF DMS CORE BLOCK DIAGRAM

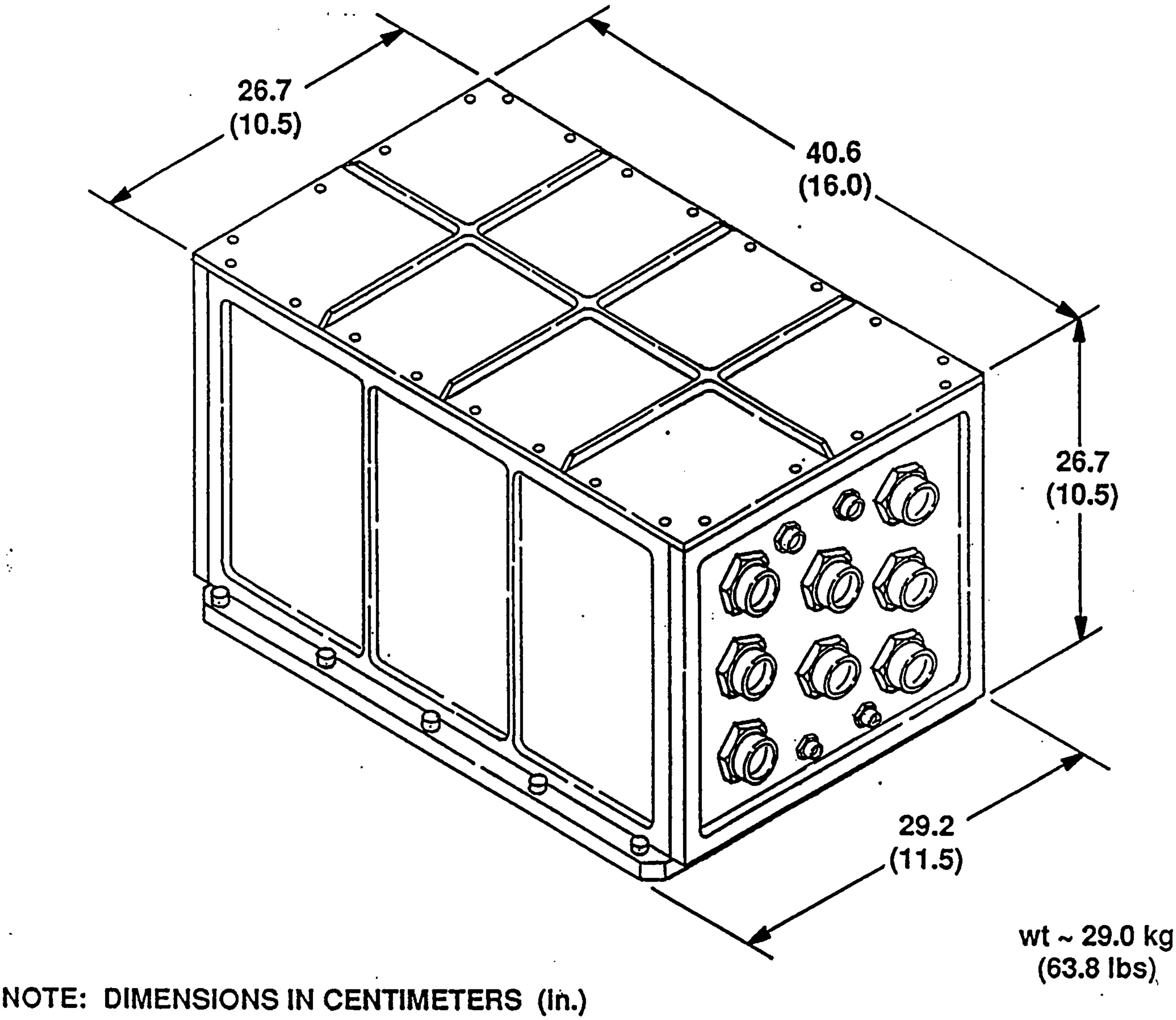


FIGURE 3.2.2.1.1-1
CORE CONTROL UNIT
ISOMETRIC DIAGRAM

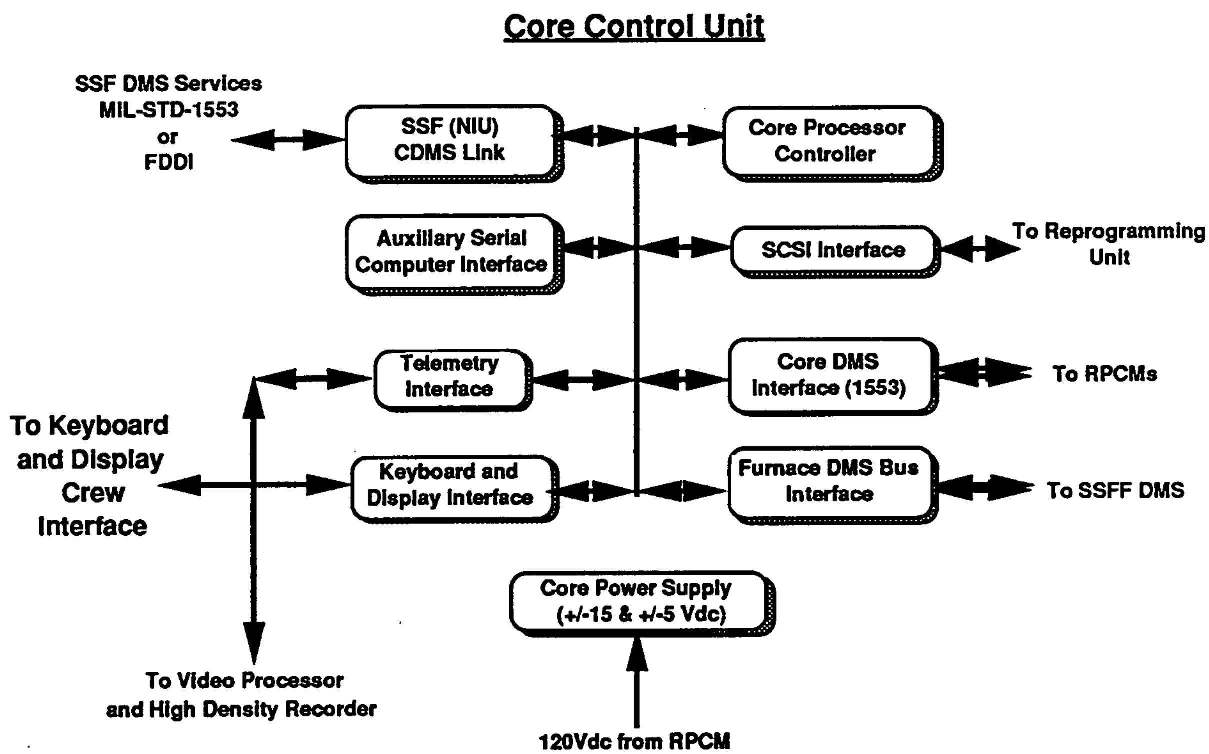


FIGURE 3.2.2.1.1-2 - CORE CONTROL UNIT

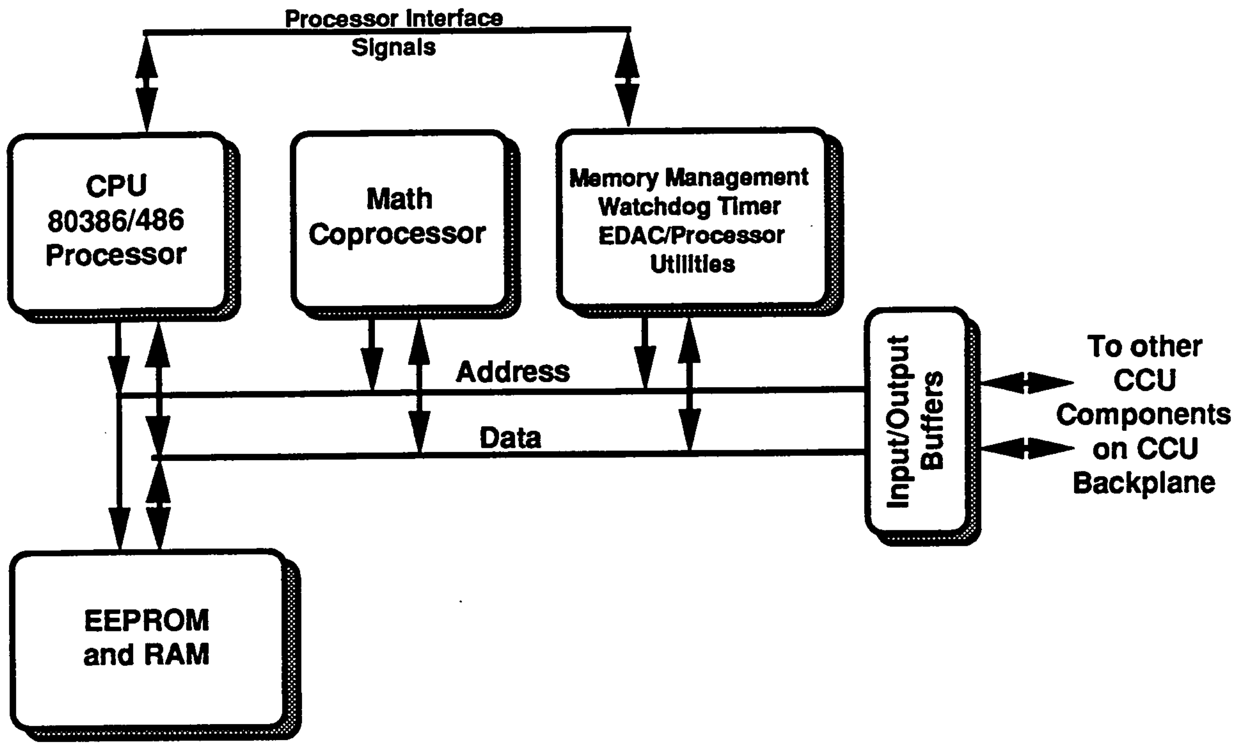


FIGURE 3.2.2.1.1.1-1
CORE PROCESSOR/CONTROLLER

The Core Processor/Controller will have a Real-Time Clock (battery backed-up) available for processor reference, which will allow the DMS to be programmed to perform certain operations at an appropriate time. This will allow the Core Processor/Controller to start operation of the Furnaces and various peripherals at a given time, while being in a low power standby mode before start-up of the experimental process. This feature will also allow for accurate processor timeline emergence after a power outage through the tracking of the procedure timeline versus furnace operation.

Some of the additional features that will be incorporated into the Core Processor/Controller design are: a watchdog timer (to allow the Core Processor/Controller to perform a self check on its operation and reset itself if necessary); Memory Management (to assist in the memory accessing and partitioning); and a buffered bus architecture (to insures that its' internal and memory bus is electrically isolated from the I/O Bus); both a polled and a maskable interrupt structure (to allow the Processor to continue other tasks until data is ready); and an I/O backplane structure based around MultiBus II. This Multibus II feature will be used to allow the Core Processor/Controller to gather information from other I/O designs in the CCU; such as communication externally with SSF via

the Network Interface Unit, and to communicate internally to the SSFF via the Furnace Bus Interface Unit (FBIU) and Core DMS Bus Interface.

3.2.2.1.1.2 SSFF Network Interface Unit - This Interface will allow the Core Control Unit to communicate with the Space Station Freedom Data Management Services. Data communication will be accomplished via a MIL-STD-1553 link to SDP-7, or via the FDDI communications protocol, through the utilization of the NIU. Both interfaces will be of a double buffered architecture which will communicate with the backplane bus of the CCU for interface to the Core Processor/Controller.

This SSFF DMS Interface (in the case of the 1553) will be based on standard Space Station Qualified hardware for the interface. In the case of the FDDI interface, this will be based on the Space Station Freedom NIU, currently under development.

3.2.2.1.1.3 SSFF Furnace Bus Interface Unit - The Furnace Bus Interface Unit will be utilized to allow the CCU to communicate with the other subsystems in the SSFF related to experiment data stimulus and monitoring(Furnace Control Units (FCU)). This unit will be based on a redundant LAN design and will provide reliable communication among the SSFF DMS components. Commands, data, configuration, and status information will all be communicated via the Furnace Bus Interface Unit.

3.2.2.1.1.4 Core DMS Bus Interface (MIL-STD-1553) - This Core Control Unit will also include a serial MIL-STD-1553 communications interface for monitoring and control of other SSFF Sub-System components (GDS, TCS, and PDS). This communications link connects the CCU with the Core Monitor and Control Unit (CMCU), the Power Conditioning and Distribution Sub-System, Remote Power Conditioning Modules (RPCM designed by SSF), the Core Power Conditioning Stimulus unit which modulates the voltages to the Experiment racks, and to the Distributed Core Monitor Units (DCMU) in each of the experiment racks. Each of these units will contain a MIL-STD-1553 Interface for command and control purposes, so each of the units will be assigned separate MIL-STD-1553 compatible addresses. This will allow the Core Control Unit to communicate with the any of them via this dedicated link for the monitoring and control of the sub-system components.

3.2.2.1.1.5 SCSI Interface - This interface will be for the communication of the Reprogramming Unit (and or hard drive if need arises) with the Core Processor Controller. It will be implemented in the standard SCSI-2 format, and will support multiple devices.

3.2.2.1.1.6 Auxiliary Serial Computer Interface - This interface will be implemented in the Core Control Unit for the contingency of hooking another computer or peripheral to the CCU, such as a GRiD, or a printer. This will allow other possibilities in system implementation and expandability.

3.2.2.1.1.7 Telemetry Interface - This interface will be used for transferring the facility and experiment data that has been collected by the Core Control Unit, to the Video Processor to be merged with the video data. The Video Processor will then send the collected data to the High Density Recorder for storage. In the event that the Video Processor is not present, this interface will connect directly to the High Density Recorder.

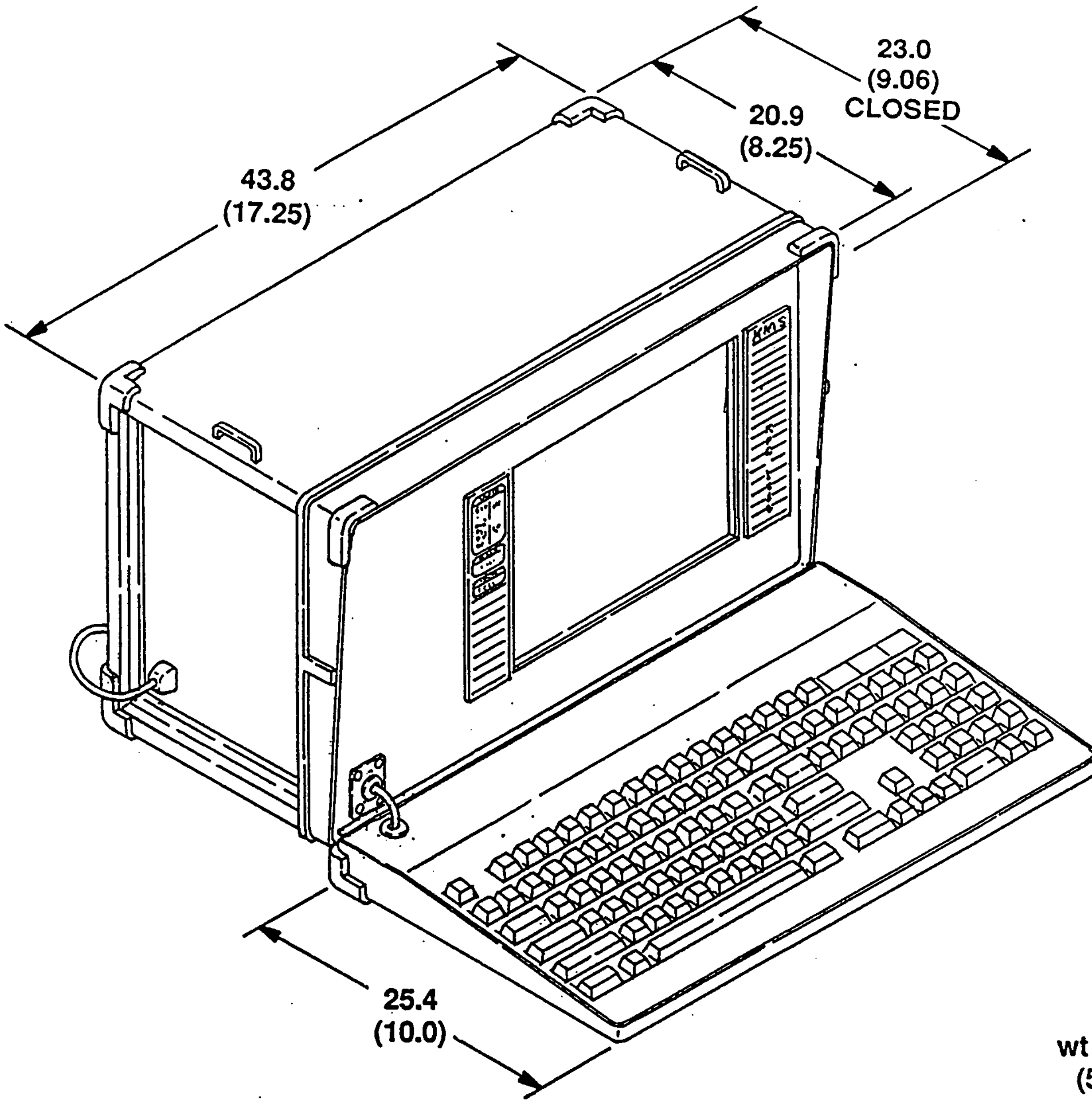
3.2.2.1.2 Reprogramming Unit - This Reprogramming Unit (SSFF DMS-RU-003) will be the high density storage device which will hold the operational programs for the Space Station Furnace Facility. These programs will control the Experiment Profiles (such as temperature characteristics, control profiles, translational control, camera positional commands, etc.) that the Space Station Furnace Facility will use to configure itself for experiment runs. When the operation of a furnace is required, the Core Processor/Controller will download the Experiment Program from the Reprogramming Unit into Electrically Erasable Programmable Read Only Memory (EEPROM) and Static Random Access Memory (SRAM or RAM) located in the Core Control Unit. It will then download the appropriate control routines to the Furnace Control Units and other DMS components.

The layout of the front panel of the CCU will be situated so that the Reprogramming Unit cartridges can be easily inserted into the Reprogramming Unit. This will facilitate upgrades of the software, as well as any necessary reconfigurations brought on by hardware installations in the facility.

The Reprogramming Unit will utilize a standard SCSI interface system for transfer of data from the drive to the CCU backplane.

3.2.2.1.3 Crew Interface Unit (Keyboard and Display Unit) - The Crew Interface Computer (SSFF DMS-CIC-002, shown in Figure 3.2.2.1.3-1) consists of a keyboard and display unit which will allow communication of the crew to the SSFF Core Computer. This will facilitate the communication of the crew to the SSFF independent of the Space Station Freedom Data Management System. A standard QWERTY (Standard) keyboard will be provided to input commands from the crew. This keyboard will be mounted to the front panel of the SSFF Core Facility for ease of operation.

The Video Display will be utilized to provide the crew with information concerning the configuration, control, status, or operation of the Space Station Furnace Facility. The Video Display will utilize a space hardened color interface and display capable of displaying video from the Video Processor video interface, and/or tabular information data/status from the Core Control Unit as the CCU monitors the Furnaces and other subsystems in the SSFF.



wt ~ 23.0 kg
(50.6 lbs)

NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.1.3-1
CREW INTERFACE COMPUTER

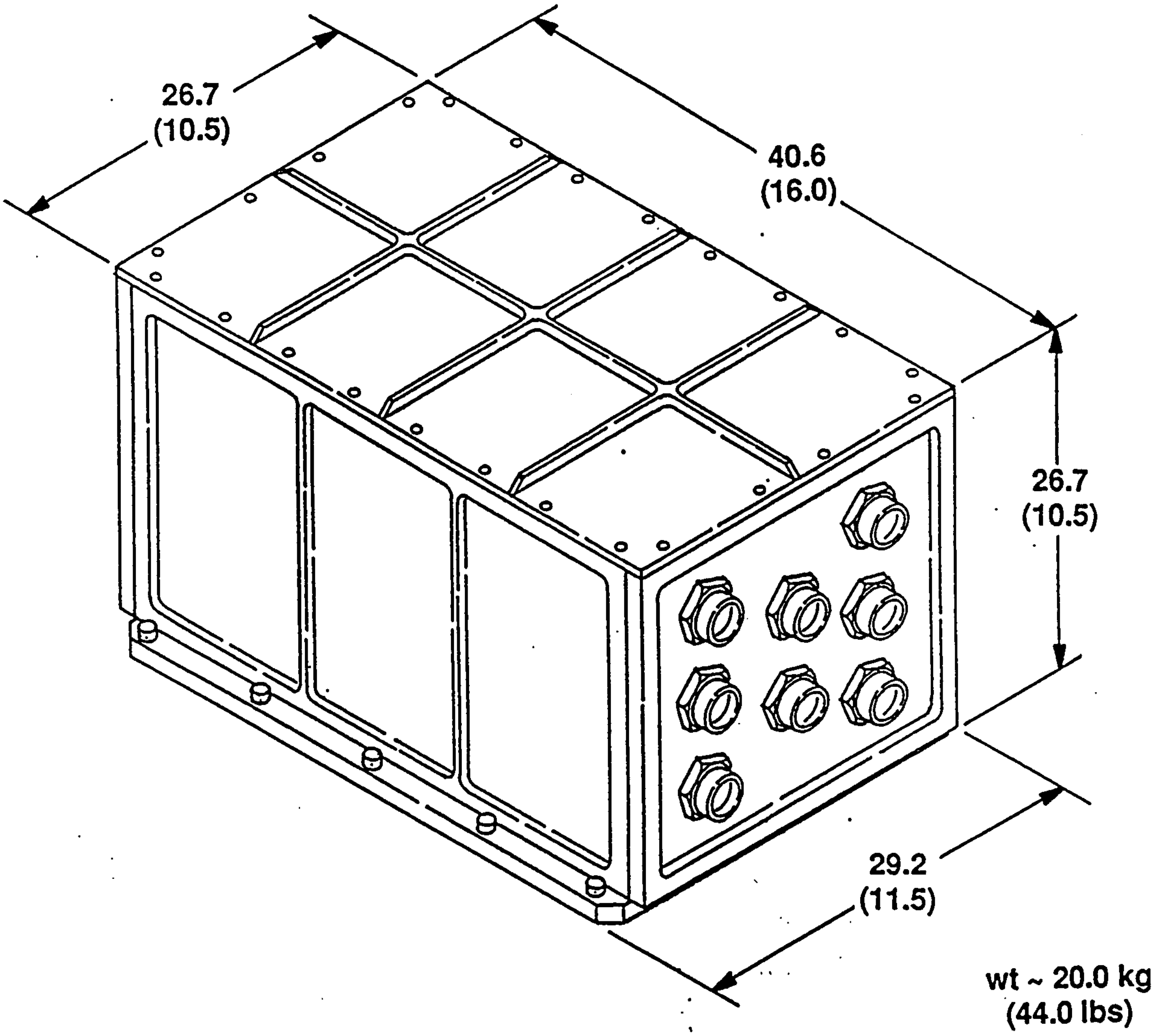
3.2.2.1.4 Core Monitor/Control Unit (CMCU) - The CMCU (SSFF DMS-CMCU-009 Core Monitor and Control Unit) will be a data acquisition and stimulus system which will provide I/O cards that monitor and control functions for the other systems in the Core Facility as an extension of the CCU. Communication to/from the CCU will be accomplished via a MIL-STD-1553 link. The Fluids, Thermal, and Power sub-systems will be monitored by this system, as well as monitoring items such as thermal conditions of other boxes. This will insure that other units in the SSFF are not overheating and in thermal runaway. If this should be the case, and any units are going over-temperature, the CMCU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS. The CMCU is shown in isometric form in Figure 3.2.2.1.4-1, and as a functional block diagram in Figure 3.2.2.1.4-2.

These interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring to insure that the other subsystems of the SSFF are operating properly. This will allow the Core Control Unit monitor the other SSFF subsystems to guarantee the safe operation of the SSFF.

3.2.2.1.5 Video Acquisition/Distribution & Processing - The requirement for video has been identified for two of the SSFF mission set experiments, the Transparent Furnace, and the Hot Wall Float Zone Furnace. The capability to satisfy the requirements of these experiments as defined in the SSFF Capability Requirements is not achievable because of limited access to the SSF communications links and bit rate limitation (<43 Mbits/sec) imposed by the SSF. In Section 1.2 of this report assumptions are made as a guide to contending with this. The SSFF Video Processor Unit is shown in Figure 3.2.2.1.5-1.

3.2.2.1.5.1 Video Processor Unit - The Furnace Facility Video Processor Unit (SSFF DMS-VPU-008 or VPU) will be designed as a unit capable of capturing NTSC/RGB(or related format video) from cameras located in experiment assemblies, and then digitizing, frame grabbing, and/or processing the resulting image. The video data (after digitization and/or any compression or processing) will then be made available to the High Density Recorder (HDR) for storage. If the data rate is not sufficiently high enough, the Removable Hard Drive (RHD) will be used as a data buffer to store a sufficient amount of data to warrant writing to the HDR. Communication and control of the Removable Hard Drive will be accomplished via a SCSI-2 interface which will be handled by the Video Processors' CPU. The CPU will also control the operation of the High Density Recorder and Playback Electronics via an RS-422 link, and will also merge non-video facility data received from the Buffer Electronics (sent by the CCU) with the video data for storage on the HDR. The SSFF Video Processor Block Diagram is shown in Figure 3.2.2.1.5.1-1.

As part of the processing available in the Video Processor, the system will be scarred include a programmable format (JPEG/MPEG) Compander which will allow for a variable compression



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.1.4-1
CORE MONITOR AND CONTROL UNIT

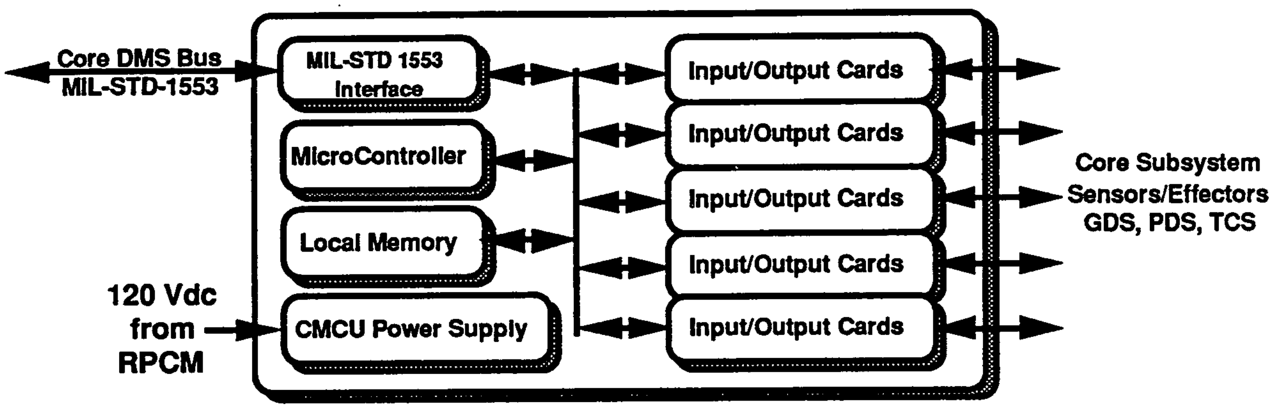
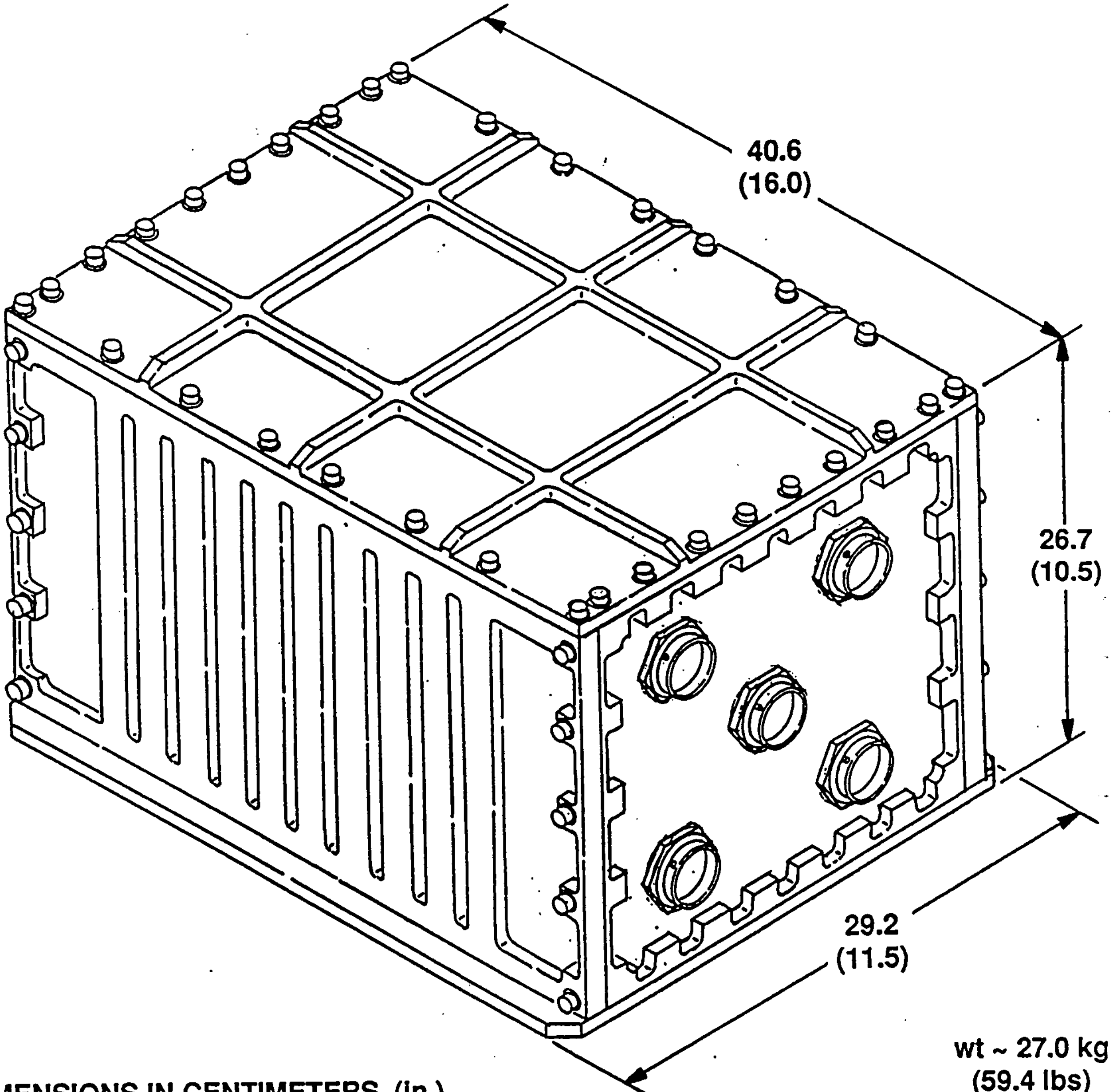


FIGURE 3.2.2.1.4-2 - CORE MONITOR/CONTROL UNIT LAYOUT



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.1.5-1
SSFF VIDEO PROCESSOR UNIT

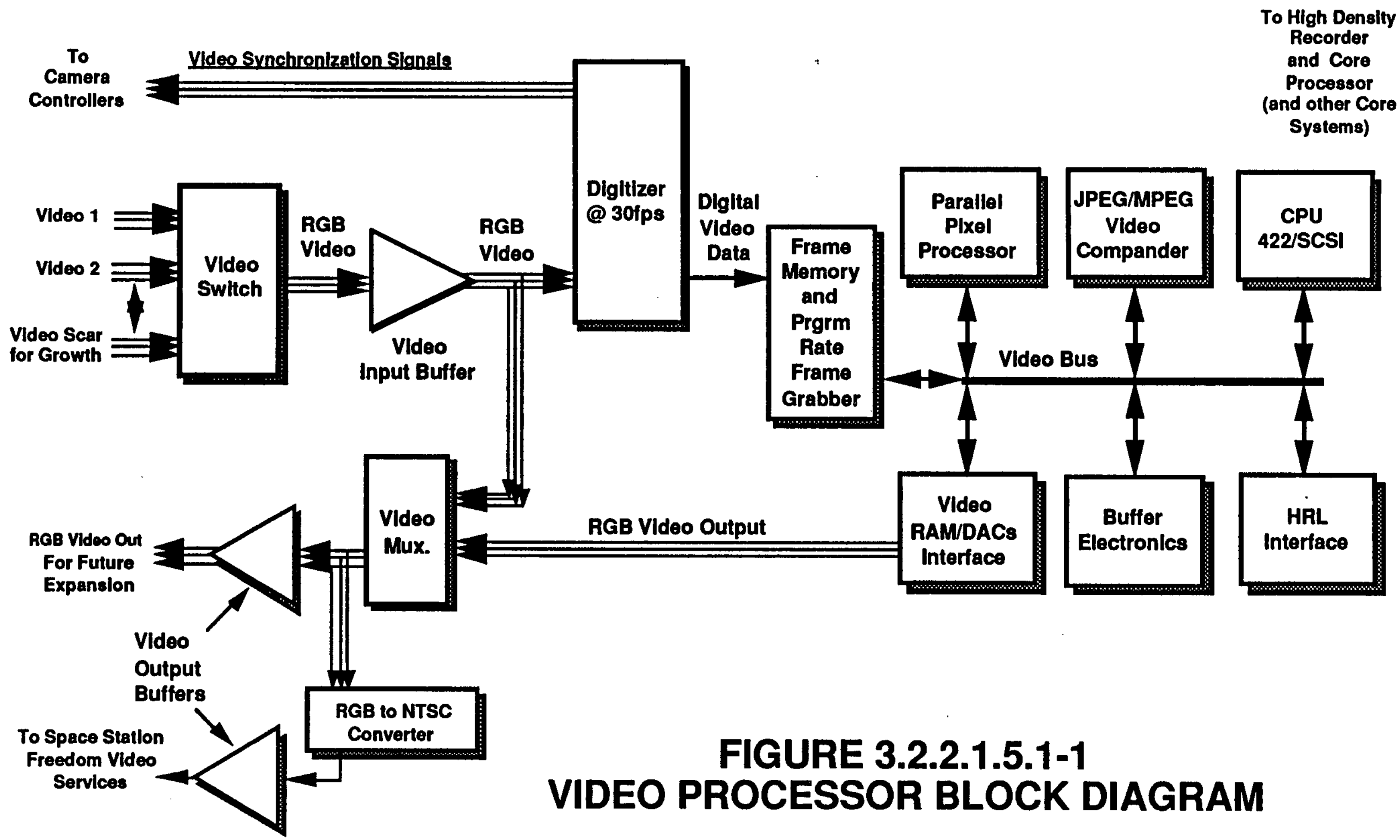


FIGURE 3.2.2.1.5.1-1
VIDEO PROCESSOR BLOCK DIAGRAM

ratio (or no compression at all) to be applied to the data for storage. The design will also be able to accommodate a video pixel processor which can do interpretation of video data, and return numerical data to the ground for evaluation.

When the Video Processor is required by the CCU to capture video data, the Core Control Unit will write selection word(s) to the video processor for the amount of compression (if desired) and TBD parameters needed for digitization. The CCU will then instruct the Video Interface to start the acquisition process. The video acquisition task will then proceed automatically (or with CCU interaction as necessary). The CCU can designate that the acquired video data can be routed to SSF Video services, storage, display, or a combination of several destinations.

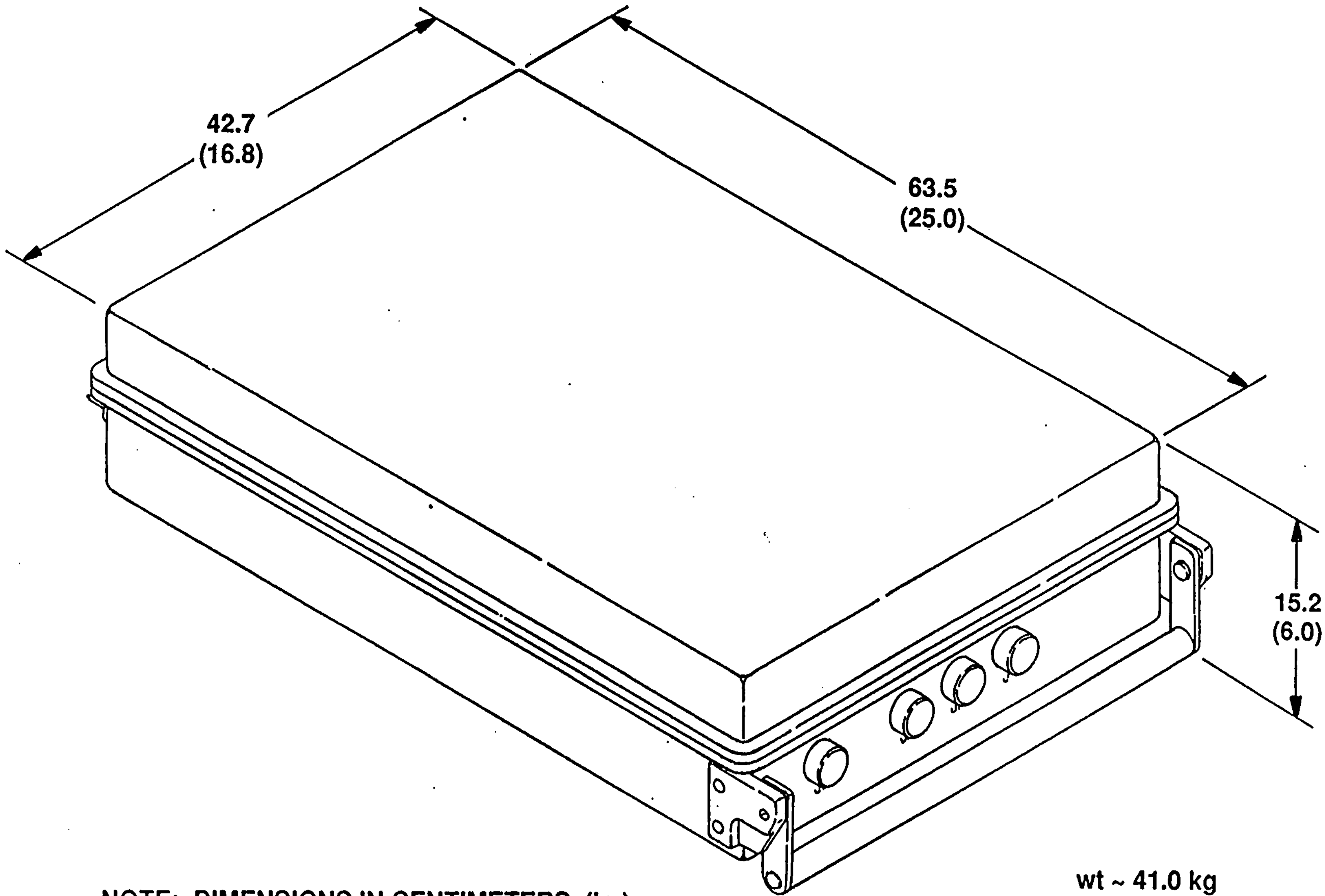
3.2.2.1.5.1.1 High Rate Data Link (HRDL) - The Video Processor will also contain the High Rate Data Link and interface will enable the SSFF to download up to 43 Mbytes of data to the ground through the High Rate Data Patch Panel and ultimately the High Rate Data Multiplexer (HRDM). The format for this interface has yet to be defined by SSF, although it is known that a payload desiring this interface will be assigned a given bandwidth of the telemetry link (and probable implementation will use the TAXI device). If this allocated bandwidth is not utilized fully, it will be filled with "filler" bits in order to maintain telemetry lock by the links' components.

3.2.2.1.6 High Density Recorder and Playback Electronics - The High Density Recorder (SSFF DMS-HDR-005, shown in figure 3.2.2.1.6-1) will have a storage capacity of 1.88 Terabits and will be used for storage of experimental data which is to be gathered. The HDR will consist of a tape drive unit (one ORU) and a set of playback electronics

The tape drive and tape will be an integral unit which will allow the Drive and the tape to both be removed as a single ORU for transport to ground. This concept will allow for ease of unloading and loading of tape as well as checkout and periodic maintenance of the heads and drive mechanism on the ground instead of in microgravity. The higher reliability playback and formatter/controller electronics will be housed in a separate unit which remain as part of the core facility in which the drive can dock.

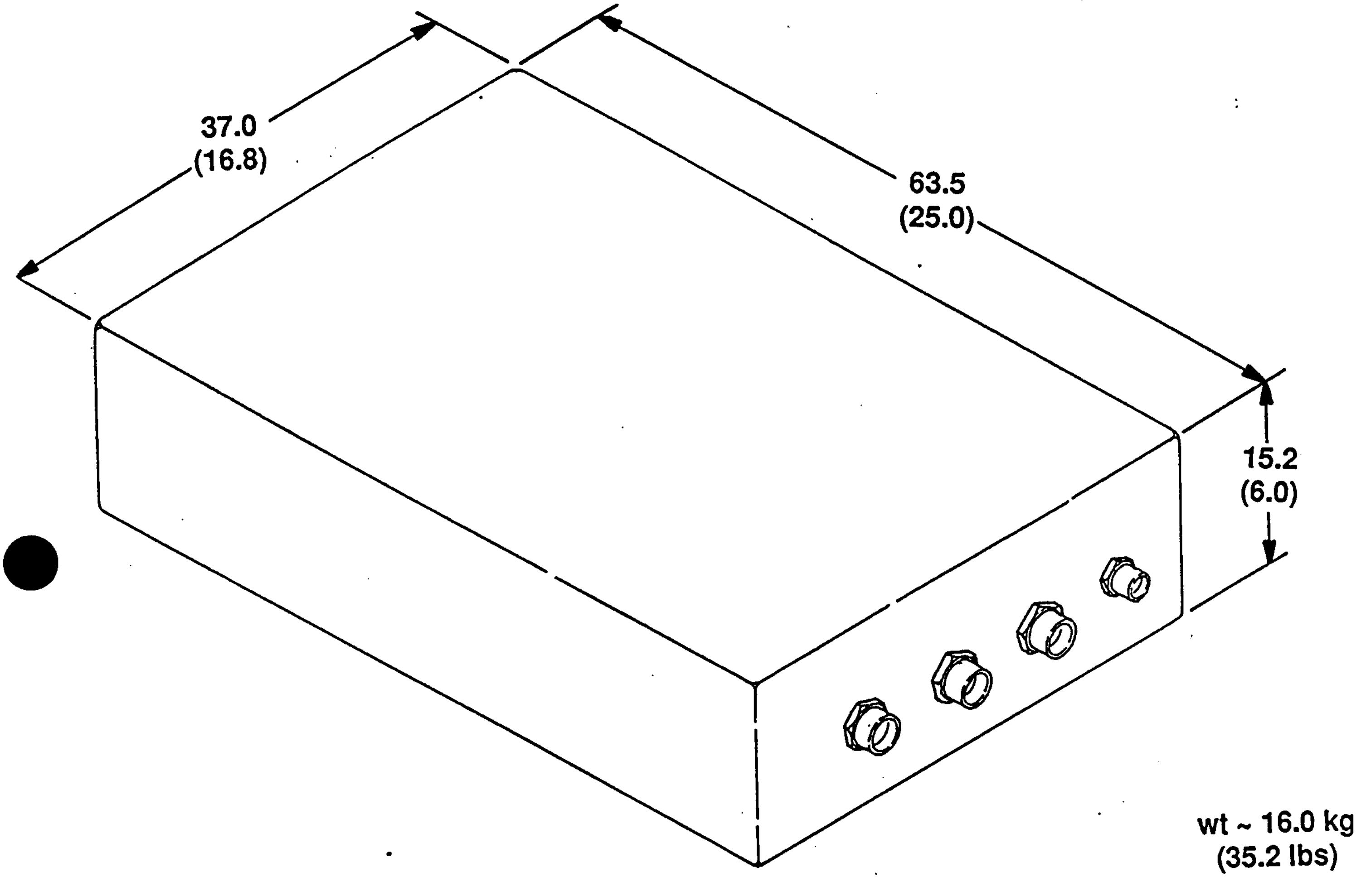
The High Density Recorder Playback Electronics (SSFF DMS-HDRPB-006, shown in figure 3.2.2.1.6-2), when playback is desired of the stored data, will take the data from the High Density Recorder and perform the operations necessary for recovery of the recorded data. This will involve equalization, bit synchronization, data decoding, and output formatting. Also included will be a complement of BIT circuitry for test of data integrity during playback.

3.2.2.1.7 Removable Hard Drive - The Removable Hard Drive is available in two sizes depending on the needs of the Facility. The first smaller capacity unit is described in section 3.2.2.1.7.1, and the larger capacity model in Section 3.2.2.1.7.2. Two positions are possible: one serving the CCU directly (SSFF DMS-RHD-004, or SSFF DMS-RHDHD-004), and the other serving as a buffer for the High Density Recorder (SSFF DMS-HDRB-007).



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2.1.6-1
HIGH DENSITY RECORDER DRIVE



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.1.6-2
HIGH DENSITY RECORDER
PLAYBACK ELECTRONICS

3.2.2.1.7.1 Removable Hard Drive 150 Meg - The first RHD unit will be a ruggedized 150 Megabyte hard disk drive contained in an aluminium cartridge. This cartridge will be mounted and locked into a separate housing assembly which opens onto the front panel of the Core Facility. This unit is shown in Figure 3.2.2.1.7.1-1.

Data and power will be supplied to the cartridge through a self aligning connector mounted in the rear. The front panel will have a sturdy handle for insertion and removal of the drive unit. The guide rails will make improper insertion impossible. The data interface for the Removable Hard Drive (RHD) will be supplied supplied by a SCSI interface which will tie the RHD into the either the VPU's CPU or into the CCUs' main bus, depending on the needs of the facility.

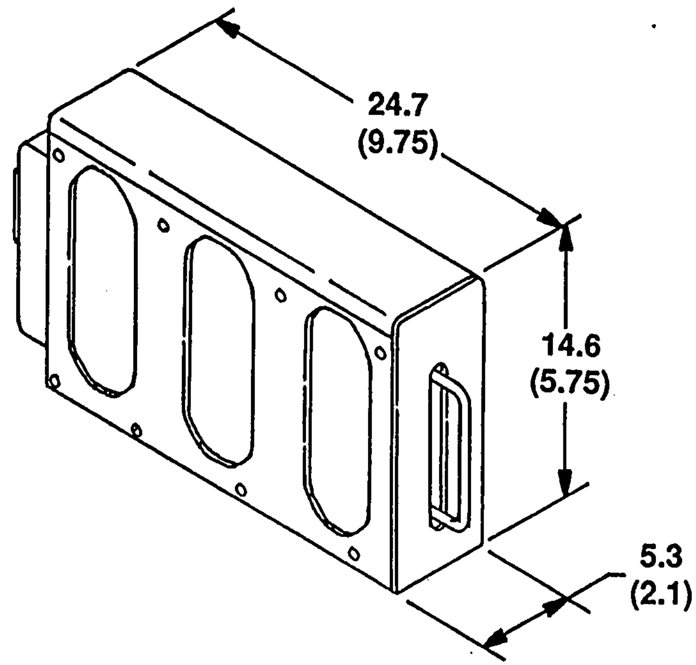
The hard-disk cartridge will be held in the housing assembly by a latching door. This door will not only lock the drive into place, but also will activate an interconnect switch for cutting off the power to the drive before the drive can be removed from the assembly. This power down feature will retract the drive's recording heads to a safe landing zone and latch them into place.

The Ruggedized Hard Drive will be utilized as non-volatile storage for the Space Station Furnace Facility. This unit can act as a temporary storage media prior to data being written to the high density tape drive, as well as separate logging of BIT history or other auxiliary data that doesn't require a great deal of storage.

3.2.2.1.7.2 Removable Hard Drive High Density (2 GigaByte) - This higher capacity system (shown in Figure 3.2.2.1.7.2-1) Removable Hard Drive 2 Gigabytes will be similar in implementation to the first unit, but with more capacity and consuming greater space. It is feasible that if no video is required by the facility, and data requirements are low, that this unit could conceivably be used for storage of the experiment data normally written to the High Density Recorder. This mass data storage system will be capable of up to 2.4 GBytes of removable storage, based on hard drive technology. The drives themselves will be hardened and encased in canisters that are capable of containing 172 MBytes per container to 1.2 GBytes.

The drive units will be capable of 15 G's operating and 60 G's non-operating. Interface will be accomplished through a SCSI interface to either the CCU or to the VPU, as required by the facility configuration..

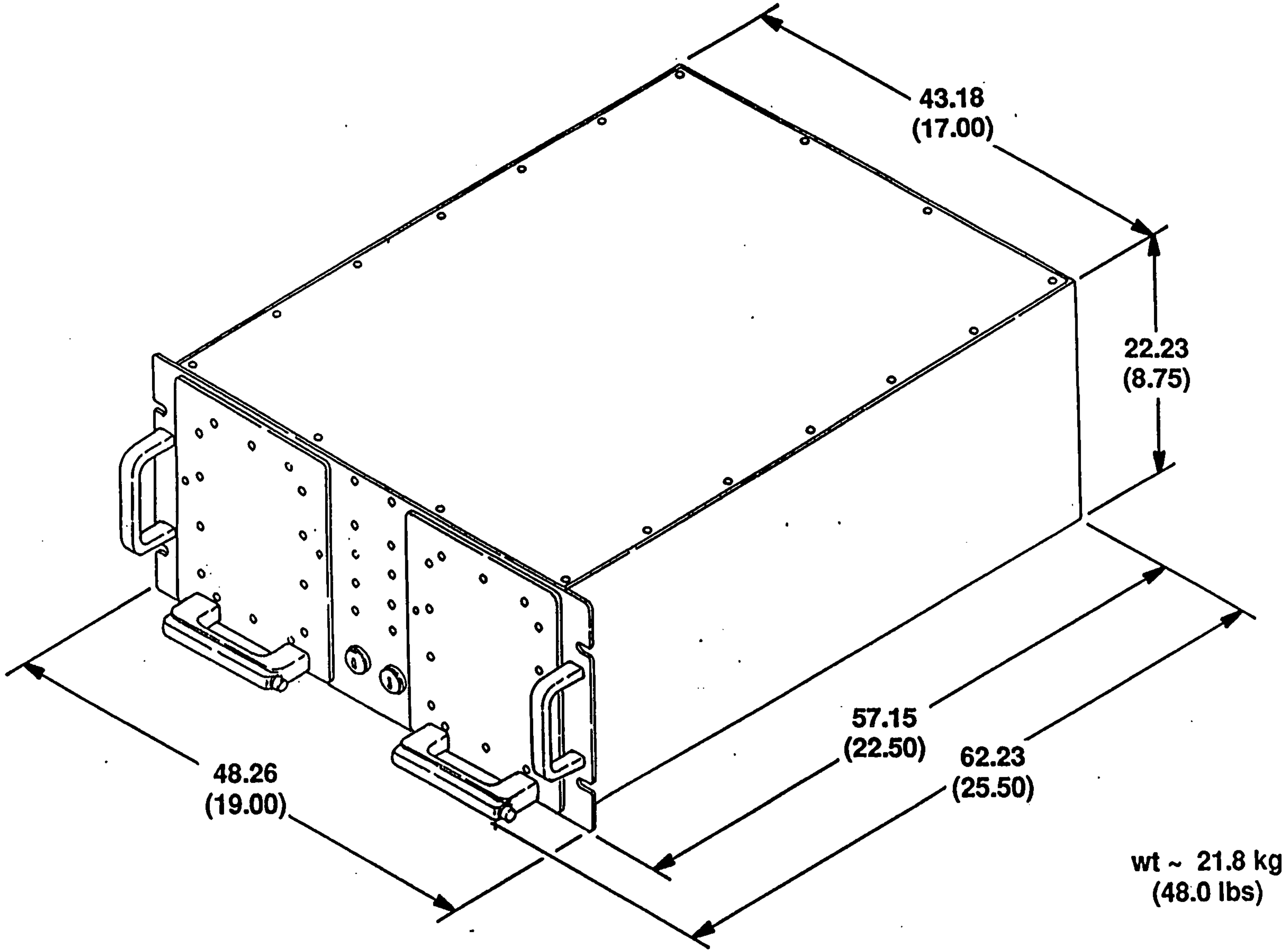
3.2.2.2 EXPERIMENT RACK INSTRUMENTATION - The experiment rack instrument will consist of a Furnace Control Unit (FCU, SSFF DMS-FCU-011), a Furnace Actuator Unit (FAU, SSFF DMS-FAU-012), and a Distributed Core Monitor Unit (DCMU, SSFF DMS-DCMU-013). This configuration will provide data acquisition (parameter monitoring) and stimulus (parameter manipulation) for both the experiments and the distributed core facility components. There will be a complement of these three items for each of experiment rack installations.



NOTE: DIMENSIONS IN CENTIMETERS (In.)

wt ~ 2.0 kg
(4.4 lbs)

FIGURE 3.2.2.1.7.1-1
REMOVABLE HARD DRIVE
150 MEG



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.1.7.2-1
REMOVABLE HARD DRIVE
2 GIGABYTE

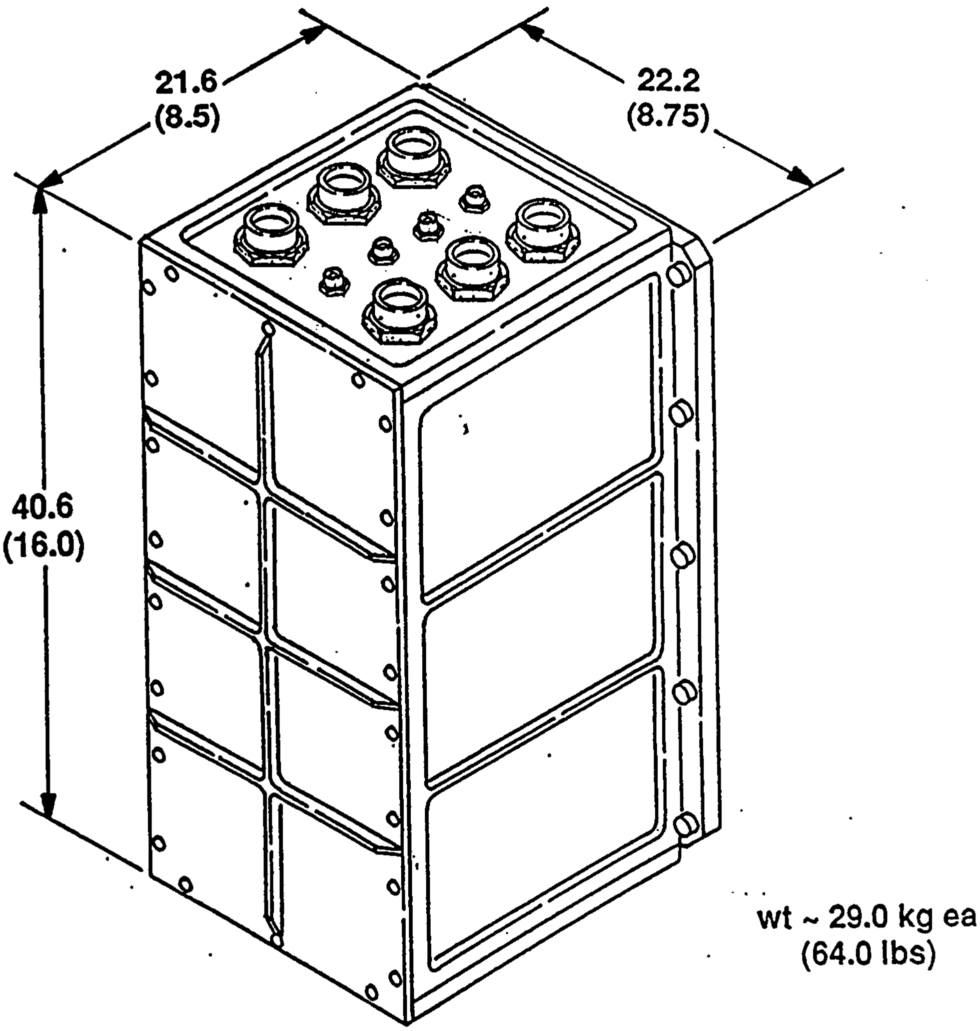
The FCU will be used as a reconfigurable furnace controller and will provide the furnace facility with housekeeping monitoring, and control functions. The FCU will also communicate with both the CCU (via the Furnace DMS Bus), and in turn will pass on control commands to the Furnace Actuator Unit for stimulus to the experiment apparatus.

The Furnace Actuator Unit will supply the control interfaces to the furnace module which will consist of: sample manipulation, furnace translation, camera interface and positioning, etc. The FCU and FAU will contain similar processors, memory and architectures as the Core Processor/Controller (in the CCU) with differences being in the number of I/Os, memory, and resulting physical sizes.

3.2.2.2.1 Furnace Controller Unit - The FCU will provide overall control of the SSFF interfaces to the furnace module for acquisition of temperature, pressure, and flow rates. The FCU will be designed as a reconfigurable unit with the following standard slots: an integral power supply; Furnace Bus Interface Unit (FBIU); a processor/memory board (386-based processor, 20 Mhz and 4 Mbyte RAM) which also contains a MIL-STD-1553 interface for communication with the Furnace Actuator Unit (Sec. 4.5.2), an auxiliary communications slot, and up to five I/O slots. The motherboard for the unit will be designed so that there are two different digital buses. The first bus structure will be dedicated to the higher speed communications between the processor and its' high speed I/Os (the Furnace Bus Interface Unit (FBIU) & the Auxiliary Communications Slot). The second design will be utilized for the communications with the various lower speed I/O interfaces (Thermocouples, Resistive Thermal Devices (RTD's), positional indicators, discretes, and other signals in need of conditioning or conversion). An isometric view of the FCU is shown in Figure 3.2.2.2.1-1, and the block diagram and card complement are shown in Figure 3.2.2.2.1-2.

3.2.2.2.2 Furnace Actuator Unit - The Furnace Actuator Unit (FAU) will be very similar in design to the FCU, except that it will be designed to primarily provide output signals to the Furnace assembly for operation of the motors and mechanisms necessary for furnace operation. Through keeping most of these high output current drive circuits out of the unit concerned with acquisition of very low level signals (the Furnace Control Unit), and each box therefore optimized for its' own particular task, the result will be an accurate and versatile system for motion control (without compromise). An isometric view of the FAU is shown in Figure 3.2.2.2.2-1, and the block diagram and card complement are shown in Figure 3.2.2.2.2-2.

The Furnace Actuator Unit will consist of a Integral Power Supply, a microcontroller board (with MIL-STD-1553 interface), and a series of I/O slots. The FAU will receive its commands via the MIL-STD-1553 link from the Furnace Control Unit, and in turn responds with data and status when requested. As is shown in Figure 3.2.2.2.2-2, the FAU contains an MIL-STD-1553 link, coupled with a supervisory microcontroller and I/O cards which will include: Experiment Sample



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.2.1-1
FURNACE CONTROL UNIT

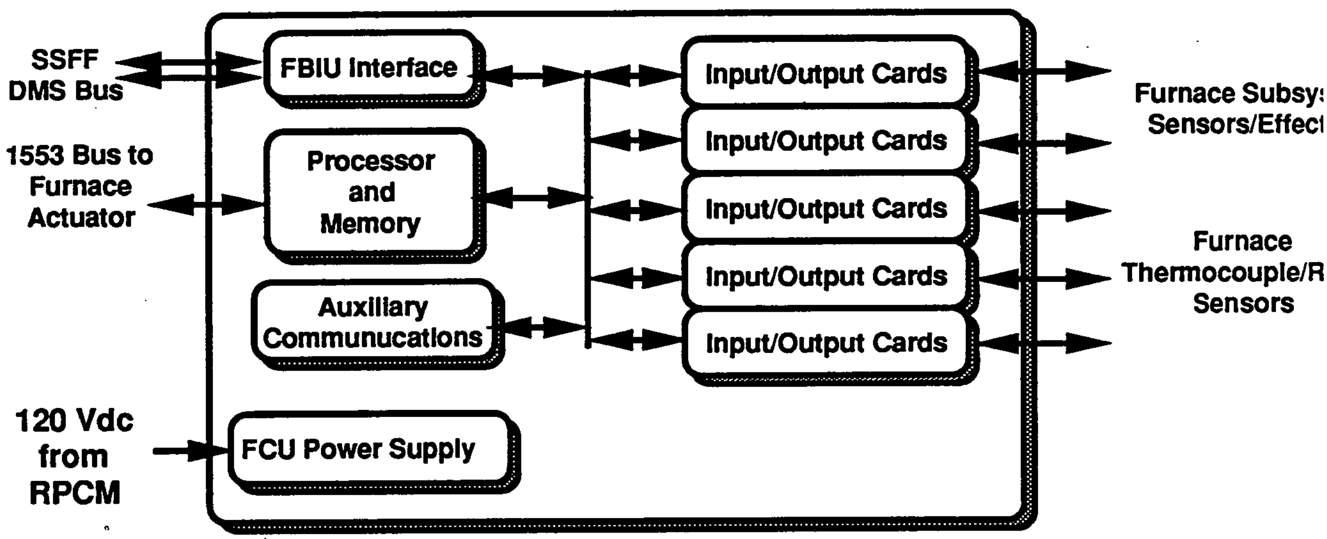
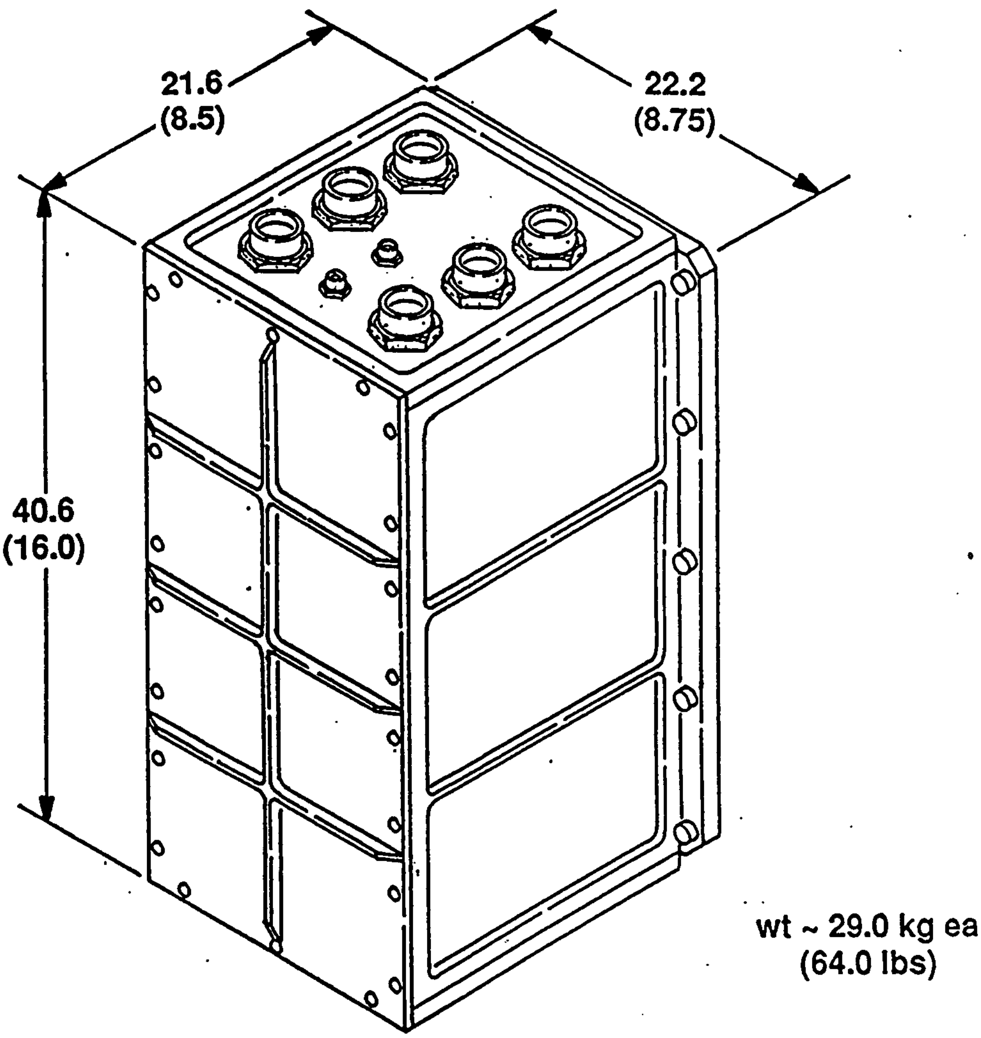


FIGURE 3.2.2.2.1-2 - FURNACE CONTROL UNIT



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.2.2-1
FURNACE ACTUATOR UNIT

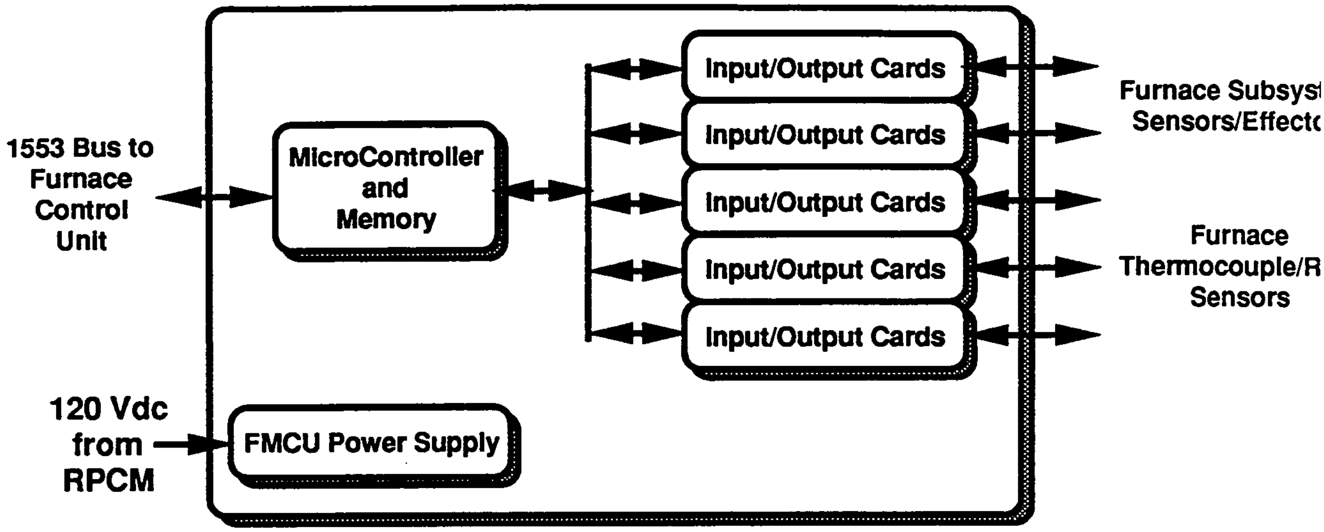


FIGURE 3.2.2.2.2-2 - FURNACE ACTUATOR UNIT

positional priver, stepper motor controller, a optically-isolated discrete output card with TBD channels, analog voltage card for generating fixed or variable analog signals, discrete inputs, and low accuracy analog input channels.

3.2.2.2.3 <u>Distributed Core Monitor Unit</u> - The Distributed Core Monitor Unit (DCMU) will be a data acquisition system which will monitor functions for the other SSFF sub-systems in the Experiment Racks as an extension of the CCU. Communication to/from the CCU is accomplished via a MIL-STD-1553 link (the Core DMS Bus). The Fluids, Thermal, and Power sub-systems will all be monitored by this system, and the DCMU also will monitor items such as thermal conditions of other boxes to insure that other systems in the Experiment Rack are not overheating. If this should be the case, and any units are going over temperature, the DCMU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS. An isometric view of the DCMU is shown in figure 3.2.2.2.3-1, while a block diagram of the unit is shown in Figure 3.2.2.2.3-2.

These DCMU interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring, to insure that the other sub-systems of the SSFF are operating properly. This extension of the CCU will allow the Core Control Unit to perform confidence monitoring upon the other sub-systems to guarantee the safe operation of the SSFF. The DCMU will also have limited capability of taking over the 1553 Core DMS Bus in case of a problem with

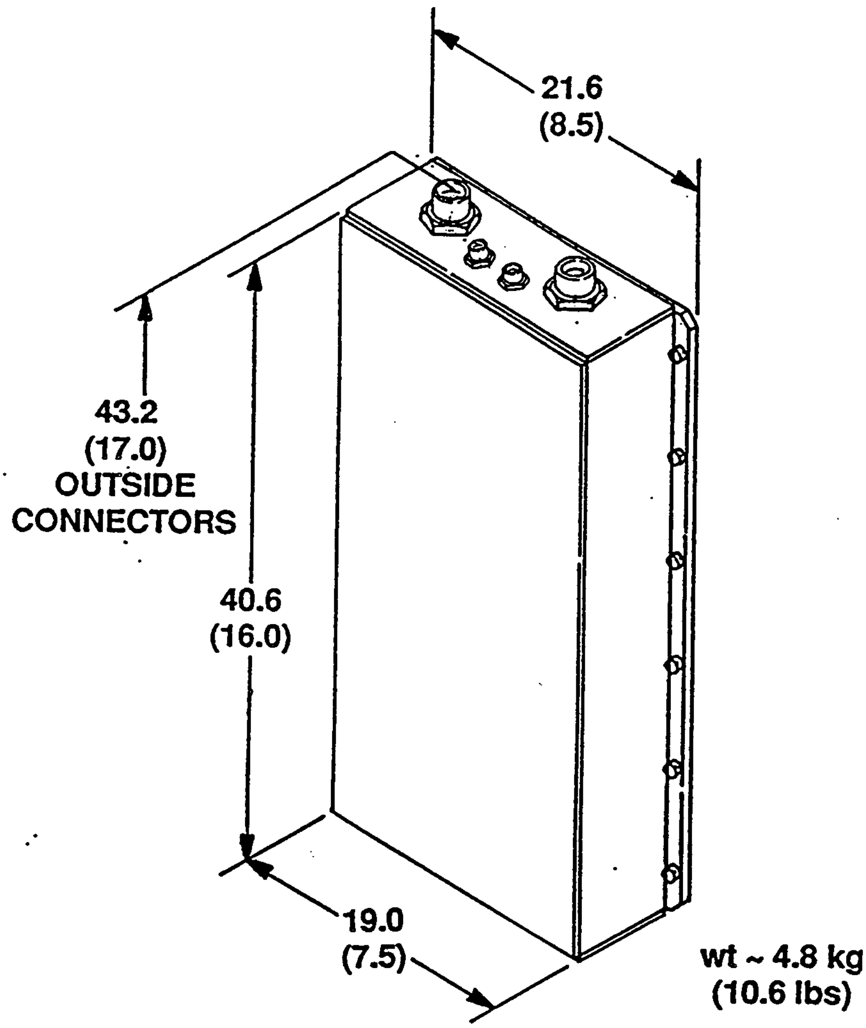


FIGURE 3.2.2.2.3-1
DISTRIBUTED CORE MONITOR UNIT

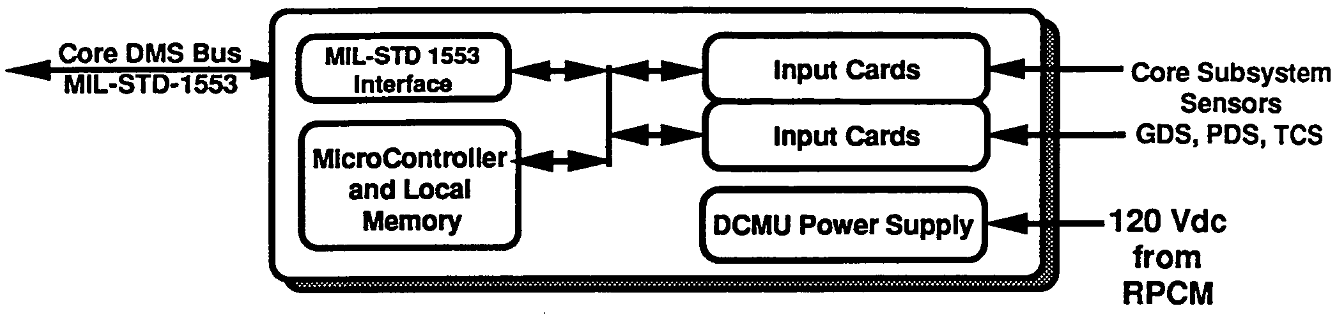


FIGURE 3.2.2.2.3-2 - DCMU BLOCK DIAGRAM

the CCU. Power, Thermal, or Gas sub-systems can be configured for a minimum safe configuration and the entire facility can be shut down if necessary.

3.3 SAFETY

The use of computer based hazard control systems is addressed in NSTS 1700.7B, Paragraph 201.1e and is designated as applicable as written in the SSF Addendum to 1700.7B. The emphasis in this requirement is placed on attaining independent/redundant controls. A single computer is considered zero fault tolerant and can serve as only one hazard control. For example, if both temperature and pressure within a furnace must be monitored and controlled by computer to prevent a hazard, two independent computer/software sets would be required, one to control temperature and one to control pressure. This is necessary to achieve the required level of fault tolerance. This requirement is presented to assure that this requirement is understood and properly implemented as the detailed design develops.

The SSFF Data Management Sub-System will accommodate this requirement through the use of redundant data buses and multiple processors involved in the monitoring and control of the facility. The primary method of safety backup control is the approach that the furnaces are monitored by both the Furnace Control Units and the Distributed Core Monitor Units (which also serve to monitor the Core services being provided to the furnaces (Thermal, Gas, and Power)). The resulting data will be transmitted back via separate data paths (Experiment DMS Bus and the Core DMS Bus) and the data will come together at the Core Control Unit which will issue commands to the Core Services via the CMCU (which is providing monitoring and control of the other sub-system Core Services). Through this method, the SSFF will provide redundant monitoring and multiple processor verification of the command stream to the services.

As an added safety measure (in the event of CCU failure), there are two added scenarios that are implemented. All of the Core Sub-System interfaces (TCS, GDS, and PDS) will be resident on the 1553 Core DMS bus, for good reason.

If the CCU were to issue (or not issue) commands that provide for the safe operation of the facility, through dynamic bus control (one of the modes of 1553) either the CMCU or the DCMU can issue commands to provide control of the Core DMS Bus limited to the safing of the facility. This would involve safe modes for the PDS, TCS, and GDS sub-systems, and therefore safe the facility (if necessary, the power could be pulled on components causing problems).

In the event that the current Bus Controller would not release the Core DMS Bus to the secondary Bus Controller (although illegal by 1553 protocol), a hardwire control over all the transceiver chip sets in all residents on the bus will be implemented to provide a non-interruptable method of terminating broadcast privileges of the current Bus Controller. This will cause the unit in question to be set into an listen only capacity. In this mode, the secondary master will implement a safe shutdown of the facility.

Through these methods, safe operation of the SSFF is insured to meet the requirements for operation aboard Space Station Freedom.

3.4 INTEGRATED RACK COMPONENT POSITION

The following Figures 3.4-1 and 3.4-2 show the location of the DMS components in the Core and Experiment Racks respectively.

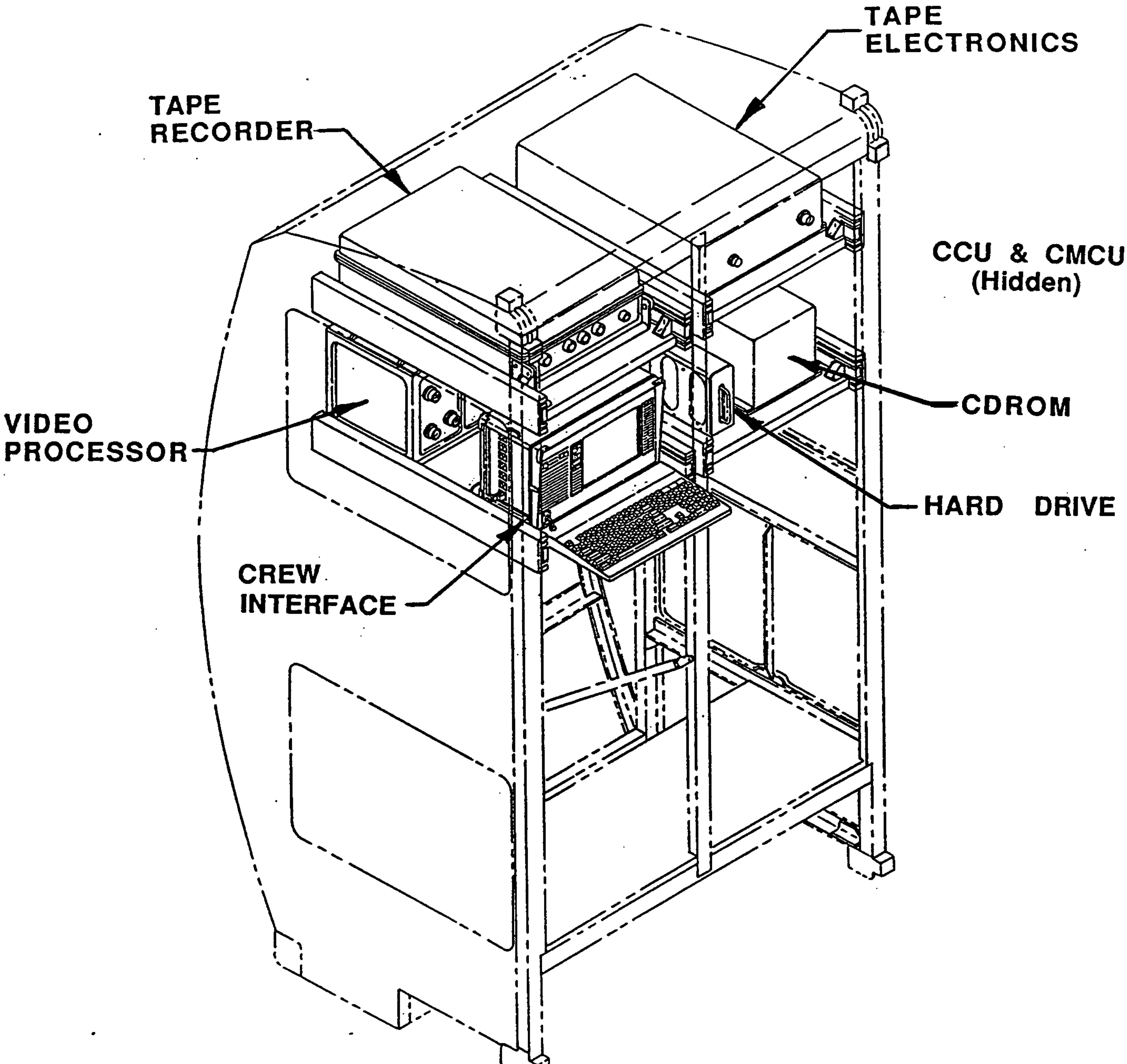


FIGURE 3.4-1
INTEGRATED CORE RACK
DMS COMPONENTS

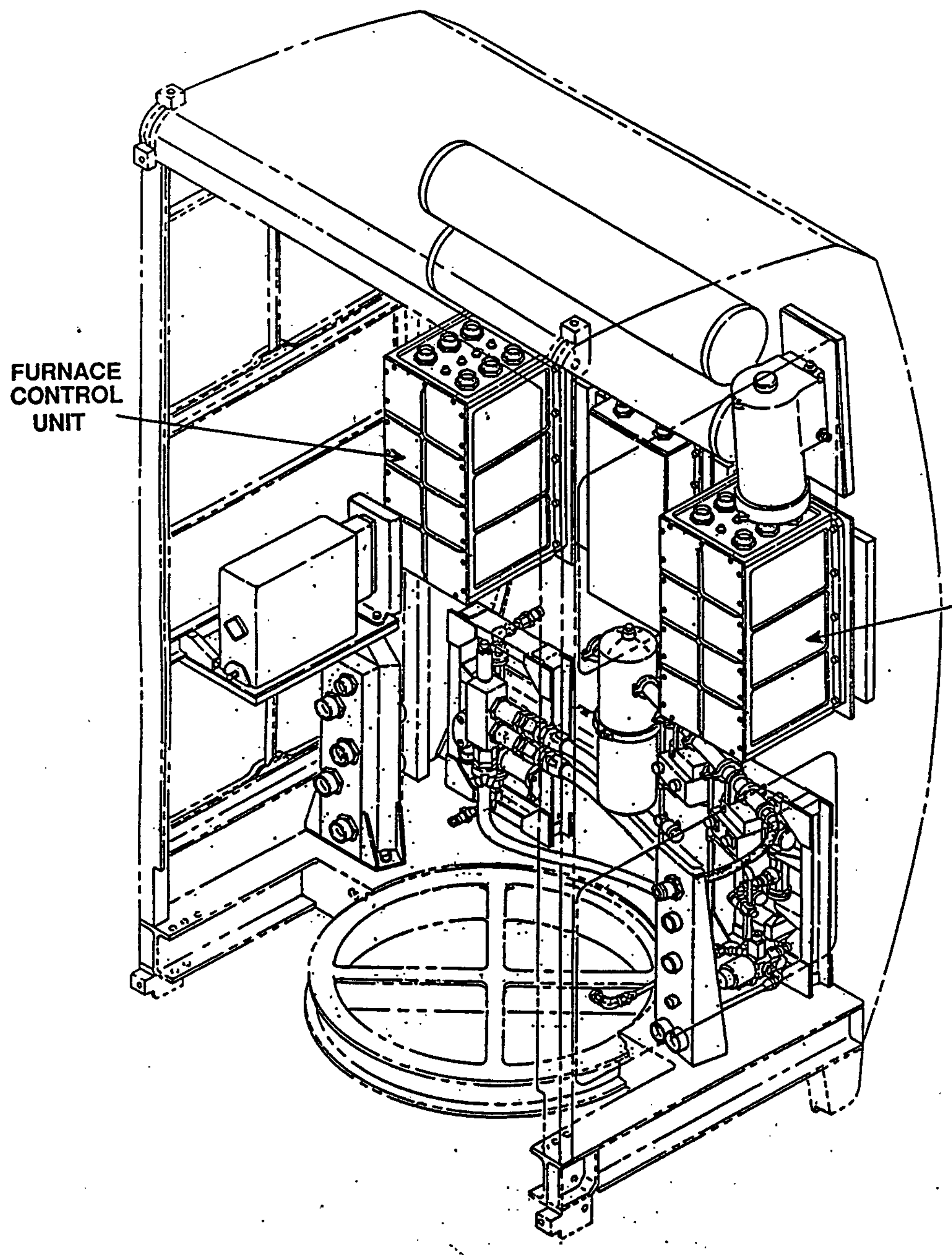


FIGURE 3.4-2
INTEGRATED EXPERIMENT RACK
DMS COMPONENTS

4. RESOURCE REQUIREMENTS

TABLE 4-1. DMS MASS PROPERTIES

Component	Quantity	Unit Mass (KG)	Total Mass (KG)
Core Control Unit	1	25	25
Furnace Control Unit (FCU)	2	27	54
Furnace Actuator Unit (FAU)	2	22	44
Core Monitor and Control Unit (CMCU)	1	19	19
Distributed Core Monitor Unit (DCMU)	2	10	20
Reprogramming Unit	1	2	2
Hard Drive 150 Megabyte	1	2	2
Hard Drive 2 Gigabyte	1	22	22
High Density Recorder	1	29	29
HDR Playback Electronics	1	18	18
Crew Interface	1	10	10
Video Processor	1	27	27
Total			241

TABLE 4-2. POWER REQUIREMENTS

Component	Quantity	Power (ea.) (Watts*)	Power Total (W*)
Core Control Unit	1	155	155
Furnace Control Unit (FCU)	2	103	206
Furnace Actuator Unit (FAU)	2	120	240
Core Monitor and Control Unit (CMCU)	1	43	43
Reprogramming Unit	1	20	20
Hard Drive (150)	1	20	20
Hard Drive (2G)	1	84	84
High Density Recorder	1	204	204
Crew Interface	1	60	60
Video Processor	1	145	145
Distributed Core Monitor Unit	2	48	96
Total			1273

TABLE 4-3. MEASUREMENT & CONTROL LIST

Furnace Input/Output Summaries

	CGF	PMZF
Analogs (AI)	123	220
Thermocouples	40	100
RTDs	40	40
Volt, Current, etc.	43	80
Discretes (DI)	68	68
Analogs (AO)	10	35
Discretes (DO)	27	27

Subsystem Interfaces		# Inputs per Para.	Unit Number	Sample Rate (sps)	Parameter Range	# of Bits (Analog)	Signal Purpose	Location
Input Signals CMCU								
DC Voltage Inputs	3	1	TCS PT-01,02,05	1	0-5 volts	8	Pressure	Core
DC Voltage	2	1	TCS-PP-01-05,06	1	0-5 volts	8	Pressure	Core
DC Voltage Inputs	1	1	TCS PP-01	1	0-5.1 volts	8	Accumulator Qty.	Core
(RTD Source) DC Voltage	1	1	TCS PP-01	1	0-5.1 vdc	8	Package Temp	Core
Differential DC	2	2	TCS FM-01,-02	1	Delta Measur.	8	Flow Rate	Core
RTD	6	1	TCS TS-01>04,11	1	Ohms	8	Temp. 3 Wire	Core
RTD	6	1	TCS TS-01>04,11	1	Ohms	8	Temp. 3 Wire	Core
Strain Guage	1	1	TCS PP-01	1	Ohms	8	Pressure Sensor	Core
Hall Effect	2	1	TCS FCV-01>02	1	0-5 volts	8	Flow Rate	Core
DC Voltage	1	1	GDS MV-03	1	Potentiometer	8	Valve Position	Core
Strain Guage	3	1	GDS PT-01>03	1	Ohms	8	(4 wire) Pressure Sensor	Core
DC Inputs	1	1	PCDS-001-005	1E+03	0-240 Vdc	8	Monitor SSF Supply	Core
Hall Effect	1	2	PCDS-001-005	1E+03	100 amps	8	Monitor SSF Supply	Core
DC Inputs	1	1	PCDS-001-006	1E+03	0-240 Vdc	8	Monitor SSF Supply	Core
Hall Effect	1	2	PCDS-001-006	1E+03	100 amps	8	Monitor SSF Supply	Core
DC Input	1	1 diff. sig.	PCDS-001-001	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-002	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-003	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-004	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-005	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-006	1E+00	0-5vdc	8	Monitor Unit Temp	Core
Rotary Optical Encoder	2	4	TCS FCV-01>02	1	Binary Readout		Valve Position	Core
Discretes - Closure	2	1	TCS SO-01>02	1	Closure		Flow on/off	Core
Discretes - Closure	4	2	GDS SV-01>04	1	Closure		Valve on/off	Core
Discrete- Open Collector	2	2	TCS SO-01>02	1	0-22v, 60ms min		Solnd. valve drive	Core
Discrete	2	2	TCS SO-01>02	1	0-22v, 60ms min		Solnd. valve drive	Core
Discrete Open Collector	4	2	GDS SV-01>04	1	0-28v, 100ms min		Solnd. valve drive	Core
Communications								
MIL-STD-1553	1	2 Buses	PCDS-001-001	N/A	N/A	N/A	RPCM Control/Monitoring	Core
MIL-STD-1553	1	2 Buses	PCDS-001-002	N/A	N/A	N/A	RPCM Control/Monitoring	Core
MIL-STD-1553	1	2 Buses	PCDS-001-003	N/A	N/A	N/A	Core Power Distributor	Core
MIL-STD-1553	1	2 Buses	PCDS-001-004	N/A	N/A	N/A	Core Power Distributor	Core
MIL-STD-1553	1	2 Buses	PCDS-002-001..040	N/A	N/A	N/A	Core Power Distributor	Core
MIL-STD-1553	1	2 Buses	PCDS-002-041..072	N/A	N/A	N/A	Core Power Distributor	Core
CPC/DMS Signals (contained in PCDS-002)								
Input Signals								
DC Input	40	1 diff. sig.	PCDS-002-001..040	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	32	1 diff. sig.	PCDS-002-041..072	1E+00	0-5vdc	8	Monitor Unit Temp	Core
Output Signals								
DC Outputs (Voltage)	40	1	PCDS-002-001..040	1E+02	0-12vdc		Power module control	Core
DC Outputs (Voltage)	32	1	PCDS-002-041..072	1E+02	0-12vdc		Power module control	Core
Discrete Outputs - Voltage	40	1	PCDS-002-001..040	1E+02	0-5vdc		On/off Control	Core
Discrete Outputs - Voltage	32	1	PCDS-002-041..072	1E+02	0-5vdc		On/off Control	Core

TABLE 4-4. - CORE RACK
DMS SUBSYSTEM INTERFACES
(TCS, GDS, PCDS)

Subsystem Interfaces		# Inputs per Para.	Unit Number	Sample Rate (sps)	Parameter Range	# of Bits (Analog)	Signal Purpose	Location
Experiment Rack #1 Signals								
DCMU and FCU #1 Signals								
Input Signals ER#1								
DC Voltage inputs	1	1	TCS PT-03	1	0-5 volts	8	Pressure	ER#1
Differential DC	1	2	TCS FM-03	1	Delta Measur.	8	Flow Rate	ER#1
RTD	3	1	TCS TS-05>07	1	Ohms	8	Temp. 3 Wire	ER#1
Hall Effect	1	1	TCS FCV-03	1	0-5 volts	8	Flow Rate	ER#1
DC Voltage	40	1 diff sig.	PCDS-006-001	1	0-24vdc	8	voltage meas.	ER#1
Hall Effect Device	40	1 diff. sig.	PCDS-006-001	1	0-10amps	8	current meas.	ER#1
Strain Guage	3	1	GDS PT-04>06	1	Ohms	8	(4 wire) Pressure Sensor	ER#1
Potentiometer	2	1	GDS SV-06,07	1	Ohms	8	Valve Position	ER#1
Contamination Monitor	2	TBD	GDS CS-01,02	TBD	TBD	TBD	Measure Contamination	ER#1
Rotary Optical Encoder	2	8	GDS SV-06,07	1	Binary Readout	4	Valve Position	ER#1
Discretes - Closure	1	2	GDS SV-05	1	Closure		Valve on/off	ER#1
Rotary Optical Encoder	1	8	TCS FCV-03	1	Binary Readout		Valve Position	ER#1
Closure	1	1	TCS SO-03	1	Closure		Flow on/off	ER#1
DC Inputs	1	1	PCDS-004-002	1E+03	0-240 Vdc	8	Monitor SSF Supply	ER#1
Hall Effect	1	2	PCDS-004-002	1E+03	100 amps	8	Monitor SSF Supply	ER#1
DC Voltage	32	1	PCDS-006-001	2E+00	24 Vdc	8	Monitor SSF Supply	ER#1
Hall Effect	32	2	PCDS-006-001	1E+03	32 amps	8	Monitor SSF Supply	ER#1
DC Input	1	1 differential signal	PCDS-004-002	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Input	1	1 differential signal	PCDS-006-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Input	1	1 differential signal	PCDS-004-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Input	1	1 differential signal	PCDS-009	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Inputs	TBD	TBD	PCDS-009	TBD	TBD	TBD	Monitor Current Pulsing	ER#1
FAU #1 Signals								
Output Signals ER#1								
Open Collector	1	2	TCS SO-03	1	0-22v, 60ms min		Solnd. valve drive	ER#1
Motor Drive	4	2	GDS SV-06,07,09,10	1	Stppr Mtr Drv.		Motor Valve Drive	ER#1
Discrete Open Collector	4	2	GDS SV-06,07,09,10	1	0-28v, 100ms min		Motor valve drive	ER#1
Discrete Open Collector	2	2	GDS SV-05, 08	1	0-28v, 100ms min		Solnd. valve drive	ER#1
MIL-STD-1553	1	2 Buses	PCDS-004-001	N/A	N/A	N/A	RPCM Control/Monitoring	ER#1

TABLE 4-5. - EXPERIMENT RACK #1 DMS SUBSYSTEM INTERFACES (TCS, GDS, PCDS)

Subsystem Interfaces		# Inputs per Para.	Unit Number	Sample Rate (sps)	Parameter Range	# of Bits (Analog)	Signal Purpose	Location
Experiment Rack #2 Signals								
DCMU and FCU#2 Signals								
Input Signals ER#2								
DC Voltage Inputs	1	1	TCS PT-04	1	0-5 volts	8	Pressure	ER#2
Differential DC	1	2	TCS FM-04	1	Delta Measur.	8	Flow Rate	ER#2
RTD	3	1	TCS TS-08>10	1	Ohms	8	Temp. 3 Wire	ER#2
Hall Effect	1	1	TCS FCV-04	1	0-5 volts	8	Flow Rate	ER#2
Rotary Optical Encoder	1	8	TCS FCV-04	1	Binary Readout		Valve Position	ER#2
Closure	1	1	TCS SO-04	1	Closure		Flow on/off	ER#2
Strain Guage	3	1	GDS PT-07>09	1	Ohms	8	(4 wire) Pressure Sensor	ER#2
Potentiometer	2	1	GDS SV-09,10	1	Ohms	8	Valve Position	ER#2
Contamination Monitor	2	TBD	GDS CS-03,04	TBD	TBD	TBD	Measure Contamination	ER#2
Rotary Optical Encoder	2	8	GDS SV-09,10	1	Binary Readout	4	Valve Position	ER#2
Discretes - Closure	1	2	GDS SV-08	1	Closure		Valve on/off	ER#2
DC Voltage	40	1 diff sig.	PCDS-007-001	1	0-24vdc	8	voltage meas.	ER#2
Hall Effect Device	40	1 diff. sig.	PCDS-007-001	1	0-10amps	8	current meas.	ER#2
DC Inputs	1	1	PCDS-005-002	1E+03	0-240 Vdc	8	Monitor SSF Supply	ER#2
Hall Effect	1	2	PCDS-005-002	1E+03	100 amps	8	Monitor SSF Supply	ER#2
DC Voltage	32	1	PCDS-007-001	2E+00	24 Vdc	8	Monitor SSF Supply	ER#2
Hall Effect	32	2	PCDS-007-001	1E+03	32 amps	8	Monitor SSF Supply	ER#2
DC Input	1	1 differential signal	PCDS-005-002	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
DC Input	1	1 differential signal	PCDS-007-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
DC Input	1	1 differential signal	PCDS-005-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
DC Input	1	1 differential signal	PCDS-010	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
Hall Effect	TBD	TBD	PCDS-010	TBD	TBD	TBD	Monitor Current Pulsing	ER#2
FAU #2 Signals								
Output Signals ER#2								
Open Collector	1	2	TCS SO-04	1	0-22v, 60ms min		Solnd. valve drive	ER#2
Motor Drive	4	2	GDS SV-06,07,09,10	1	Stppr Mtr Drv.		Motor Valve Drive	ER#2
Discrete Open Collector	4	2	GDS SV-06,07,09,10	1	0-28v, 100ms min		Motor valve drive	ER#2
Discrete Open Collector	2	2	GDS SV-05, 08	1	0-28v, 100ms min		Solnd. valve drive	ER#2
MIL-STD-1553	1	2 Buses	PCDS-005-001	N/A	N/A	N/A	RPCM Control/Monitoring	ER#2

TABLE 4-6. - EXPERIMENT RACK #2 DMS SUBSYSTEM INTERFACES (TCS, GDS, PCDS)

5. ISSUES AND CONCERNS

ISSUES AND CONCERNS

ISSUE	PROPOSED RESOLUTION
• SSF DMS interfaces are not clearly defined.	• The SSFF DMS Concept is designed in a modular fashion. • SSFF utilizes the FDDI and HRDL.
• Video Processor growth accommodation and scarring needs to be identified more fully.	• The SSFF DMS Concept utilizes a modular approach to meet the Science Requirements and to facilitate upgrade as new technology becomes available.
• The SSFF DMS is impacted by unscheduled outages or brownouts of Space Station Freedom Power.	• The SSFF DMS Concept does the following to insure safety and good science from the facility. - Monitoring of SSF Power. - Automatic Safing - Ancillary data requested from SSF DMS alert SSFF of impending power outages. - Holdup capacity and nonvolatile storage incorporated into design.
• Data Generation Rates	• SSFF has sought the highest density recording technology available for non-volatile storage.

APPENDIX A
TRADES AND ANALYSES

APPENDIX A

Future trades and analyses that may be conducted and may be necessary as the design develops are:

1. SSF data interface: The SSFF must interface to the SSF DMS for top level management and control, communications to the ground and crew, and to access services e.g. mass storage, that are provided via the DMS by the Space Station. There are five options that are available to the payload rack. Each of these will be analyzed and compared to the others to determine the most appropriate. Since DMS resources are in a continuous state of flux, this is a trade that must be done often.

2. Mass storage: The SSFF requirement for mass storage is to accommodate different experiment timelines and programs and to permit temporary archiving of science mission data. These requirements need to be reviewed to determine the most appropriate medium as technology and SSF capabilities change. Candidates for this analysis will include the SSF Mass Storage Unit (MSU), SSF ZOE recorder (if implemented), local hard disk (optical and magnetic), tape (optical and magnetic), and solid state memory.

3. Displays: Even though a Video display selection has been made, advances in technology point out that this must be tracked to have a design in excess of the state of the art today.

4. The Reprogramming of Experiments: This trade study has been done to assess the feasibility of different technologies for use in the software reconfiguration of the SSFF. Some of the technologies include: CDROM, magnetic tape, WORM drives, EEPROM cards, etc. Even with a selection is made for today, it is possible, due to the modularity of the SSFF to upgrade at a later time. Advances in technology might prove advantageous to perform an upgrade in the future. This is an option that must be periodically reassessed.

APPENDIX B

COMPONENT DATA

APPENDIX B

SSFF DMS-CCU-001	Core Control Unit
SSFF DMS-CIC-002	Crew Interface Computer
SSFF DMS-RU-003	Reprogramming Unit
SSFF DMS-RHD-004	Removable Hard Drive
SSFF DMS-RHDHD-004	Removable Hard Drive High Density
SSFF DMS-HDR-005	High Density Recorder
SSFF DMS-HDRPB-006	High Density Recorder Playback Electronics
SSFF DMS-HDRB-007	Removable Hard Drive
SSFF DMS-VPU-008	Video Processor Unit
SSFF DMS-CMCU-009	Core Monitor and Control Unit.
SSFF DMS-CPCS-010-001, -002	CPC Stimulus
SSFF DMS-FCU-011	Furnace Control Unit
SSFF DMS-FAU-012	Furnace Actuator Unit
SSFF DMS-DCMU-013	Distributed Core Monitor Unit

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Core Controller Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: Core Rack
P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 25
Length (cm): 25.4
Width (cm): 37.47
Height (cm): 25.4
Power: 155
Specification ID: SSFF CEI Specification, SSFF DMS-CCU-001 Core Control Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Core Control Unit (CCU), communicates with the SSF CDMS system, controls and monitors the other SSFF Systems, logs data, and displays the status information of the experiments undertaken by the furnaces in the SSFF. There are many different subsystems contained in the CCU: a Space Station Freedom DMS Network Interface Unit (NIU); SSF Bus Interface Unit (MIL-STD-1553); Furnace Control Bus Interface Unit (FBIU); Core DMS Bus Interface (MIL-STD-1553); Core Processor/Controller (CPC); Local Memory for the CPC consisting of EEPROM/RAM; Small Computer System Interface (SCSI); Video Telemetry Interface; Auxiliary Serial Computer Interface; and a Power Supply.

Potential Uses: Space Station Interface, overall process orchestration, monitoring, and control, timeline control.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Crew Interface Computer
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: Core Rack
P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 10
Length (cm): 45.72
Width (cm): 42.55
Height (cm): 35.4
Power: 60
Specification ID: SSFF CEI Specification, SSFF DMS-CIC-002 Crew Interface Computer
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: PC/AT compatible computer features a 9.7" 640 x 480 pixel VGA compatible active matrix display, 80386 or 80486 Processor, 120 MByte ruggedized hard drive, 101 key keyboard with track ball, EISA Bus Option, Video digitizer board for viewing RGB or NTSC video along with tabular data.

Potential Uses: GRiD type application workstation for interface to computers, and for reconfiguration/control/monitoring.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Drive (Storage Unit)
Last Update: 4/4/92
Item Name: Reprogramming Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 2 Kg
Length (cm): 18
Width (cm): 15
Height (cm): 6
Power: 20 watts
Specification ID: SSFF CEI Specification, SSFF DMS-RU-003 Reprogramming Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: Holds Facility and Experiment configuration, time lines, and scenarios, in a non-volatile format for easy reconfiguration of facility and experiment equipment. EEPROM Cartridge based for high reliability (MTBF 70,000 hr). 40 Meg available now. 100 Megabyte available in near future (93).

Potential Uses: Mass, non-volatile storage of data for other pieces of equipment aboard space station. Conceivable uses involve experiment data storage for low rate generation payloads during MTC, or as an effective mass storage media during PMC when crew change out of media is possible. Removability of media facilitates ease of transport of new configurations of facility or experimental hardware with increment trips of NSTS during MTC.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Hard Drive
Last Update: 4/4/92
Item Name: Removable Hard Drive
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 3
Length (cm): 25
Width (cm): 6
Height (cm): 20
Specification ID: SSFF CEI Specification, SSFF DMS-RHD-004 Removable Hard Drive
Power: 10 max
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The RHD unit will be a ruggedized 150 Megabyte hard disk drive contained in an aluminium cartridge. This cartridge will be mounted and locked into a separate housing assembly which opens onto the front panel of the CCU.

Data and power will be supplied to the cartridge through a self aligning connector mounted in the rear. The front panel will have a sturdy handle for insertion and removal of the drive unit. The guide rails will make improper insertion impossible. The Data interface for the Removable Hard Drive (RHD) will be supplied supplied by a SCSI interface which will tie the RHD into the CCUs' main bus.

The hard-disk cartridge will be held in the housing assembly by a latching door. This door will not only lock the drive into place, but also will activate an interconnect switch for cutting off the power to the drive before the drive can be removed from the assembly. This power down feature will retract the drive's recording heads to a safe landing zone and latch them into place.

The Ruggedized Hard Drive will be utilized as non-volatile storage for the Space Station Furnace Facility. This unit can act as a temporary storage media prior to data being written to the high density tape drive, as well as separate logging of BIT history or other auxiliary data that doesn't require a great deal of storage.

Potential Uses: Memory buffer for High Density Recorder, storage of Experiment or Facility log data.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Hard Drive - High Density
Last Update: 4/4/92
Item Name: Removable Hard Drive
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 22
Length (cm): 62.23
Width (cm): 48.26
Height (cm): 22.23
Specification ID: SSFF CEI Specification, SSFF DMS-RHDHD-004 Removable Hard Drive High Density
Power: 200 max
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: Mass Storage system capable of up to 2.4 GBytes of removable storage, based on hard drive technology. The Drives themselves are hardened and encased in canisters that are capable of containing 172 MBytes per container to 1.2 GBytes.

The drive units are capable of 15 G's operating and 60 G's non-operating. Interface is accomplished through a SCSI interface.

Potential Uses: Memory buffer for High Density Recorder, storage of Experiment or Facility log data.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Digital Tape Drive
Last Update: 4/4/92
Item Name: High Density Recorder Drive
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 29
Length (cm): 64
Width (cm): 43
Height (cm): 14
Power: 70
Specification ID: SSFF CEI Specification, SSFF DMS-HDR-005 High Density Recorder
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The HDR will have a storage capacity of 1.88 TeraBits and will be used for storage of experimental data which is to be gathered. The HDR will consist of a formatter and a tape drive unit.

The formatter will take the data from either the optional high speed data bus (or from the standard backplane I/O bus) and will log this data with header information, add Reed/Solomon Code, and Error Detection And Correction (EDAC) data, serialize the results, and feed the resulting data to the tape drive for storage. The formatter/controller will also control the operation (ramp up, record, playback, ramp down, fast forward, rewind) of the tape drive itself.

The tape drive and tape will be an integral unit which will allow the Drive and the tape to both be removed as a single unit for transport to ground. This concept will allow for ease of unloading and loading of tape as well as checkout and periodic maintenance of the heads and drive mechanism on the ground instead of in microgravity. The higher reliability playback and formatter/controller electronics will be housed in a separate unit which remain as part of the core facility in which the drive can dock.

Potential Uses:

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: High Density Recorder Playback Electronics
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 18
Length (cm): 63.5
Width (cm): 42.67
Height (cm): 13.34
Power: 134
Specification ID: SSFF CEI Specification, SSFF DMS-HDRPB-006 High Density Recorder Playback Electronics
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The HDR Playback Electronics, when playback is desired of the stored data on the High Density Recorder, takes the data and performs the operations necessary for recovery of the recorded data. This involves equalization, bit synchronization data decoding, and output formatting. Also included is a compliment of BIT circuitry for test of data integrity during playback.

Potential Uses: unformatting of data from Helical Scan Digital Recorders.

Status

Hardware Availability Information-
  Location: TBD
  H/W Status: Conceptual Design Phase
  Delivery Date (New Hardware): N/A
  Flight Manifest: MB-10
  Quantity:

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Digital Data Storage Device
Last Update: 4/4/92
Item Name: High Density Recorder Buffer
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 2
Length (cm): 25
Width (cm): 6
Height (cm): 23
Specification ID: SSFF CEI Specification, SSFF DMS-HDRB-007 Removable Hard Drive
Power: 10 max
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: Buffer storage of data to be stored on the High Density Recorder to avoid problems with start up and loading of the recorder. Removable hard drive technology.

Potential Uses: Extra storage capacity for BIT information or other facility data.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Video Processor Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 27
Length (cm): 25.4
Width (cm): 48.9
Height (cm): 25.4
Power: 145
Specification ID: SSFF CEI Specification, SSFF DMS-VPU-008 Video Processor Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Furnace Facility Video Processor (VP) will be designed as a unit capable of capturing NTSC (or related format video) from CCD imager arrays located in furnace assemblies, and then digitizing, frame grabbing, and/or processing the resulting image. The video data (after digitization and any compression or processing) is then made available to the Furnace Facility Processor for additional evaluation and/or storage in the High Density Recorder.

As part of the processing available, the system will be scarred include a JPEG/MPEG Standard Compander which will allow for a variable compression ratio (or no compression at all) to be applied to the data for storage. The design will also be able to accommodate a video pixel processor which can do interpretation of video data, and return numerical data to the ground for evaluation.

When the Video Interface is required by the CCU to capture video data, the Core Control Unit will write selection word(s) to the video processor for the amount of compression (if desired) and TBD parameters needed for digitization. The CCU will then instruct the Video Interface to start the digitization process. When this task is complete, the Video Interface will alert the CCU that the digitization task has been completed through the initiation of an interrupt. This completed data can then be routed to the destination of the CCU's choice; for storage, display, and/or downlink.

The VPU also contains a CPU to control the operation of the High Density Recorder, Playback Electronics, and HDR Buffer via an RS-422 link, and is also capable of merging non-video facility data with the video data for storage on the HDR. Also included is an HRDL interface for transmission of data to the SSF HRDL Patch Panel and thereby to ground.

Potential Uses: Processing of video data, compression, decompression.

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Core Monitor and Control Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 20
Length (cm): 25.4
Width (cm): 34.29
Height (cm): 25.4
Power: 43
Specification ID: SSFF CEI Specification, SSFF DMS-CMCU-009 Core Monitor and Control Unit.
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The CMCU will be a data acquisition and stimulus system which will provide I/O cards that monitor and control functions for the other systems in the Core Facility. Communication is accommodated with the Core Control Unit in the CMCU design through a 1553 link on which the CMCU is a Remote Terminal. The CMCU responds to requests for data by the CCU which supervises the operation of the other subsystems in the Core. The Fluids, Thermal, and Power systems will all be monitored by this system, and monitors items such as thermal conditions of other boxes to insure that other systems in the SSFF are not overheating and in thermal runaway. If this should be the case and any units are going over temperature, the CMCU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS.

These interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring, to insure that the other subsystems of the SSFF are operating properly. This will allow the Core Control Unit to perform confidence monitoring upon the other subsystems to guarantee the safe operation of the SSFF.

Potential Uses: Remote data acquisition and control system.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: CPC Stimulus
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 27
Length (cm): 25.4
Width (cm): 31.75
Height (cm): 25.4
Power: 44
Specification ID: SSFF CEI Specification, SSFF DMS-CPCS-010-001, -002 CPC Stimulus
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Core Power Conditioner Stimulus (CPCS) contains the current modulation devices for the programming and control of the different heater elements in each of the furnaces. The CPCS receives its instructions from either the CCU or the FDACS to set the heater elements to a certain level of current. This information is transferred to the CPCS via the SSFF DMS Bus, which links the CCU, the FDACS, and the CPCS. The CPCS consists of: a Mil-STD-1553 interface for communication with the CCU (which transfers commands and data from the CCU to the CPCS); the CPCS Microcontroller (CPCSM), processes and controls data within the CPCS unit; CPCS Analog Control Module CPCS ACM, generates voltages to set the DC/DC Converters and feeds this voltage to them via twisted shielded pairs of wires; the DC/DC converters, which control the current supplied to the furnace heater elements. The Core Power conditioners have their major control algorithms and experiment profiles are all contained in the Core and downloaded to the CPCS1553 for local storage by the Power Microcontroller. These routines are then invoked via commands received from the CCU, dictating the change of element currents, report of status, running of BIT, or whatever other actions are defined by the firmware.

Potential Uses: Control of Thermo Electric Devices, or other transducers which require a voltage modulation stimulus.

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Data Acquisition System
Last Update: 4/4/92
Item Name: Furnace Control Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 27
Length (cm): 25.4
Width (cm): 47.63
Height (cm): 25.04
Power: 103
Specification ID: SSFF CEI Specification, SSFF DMS-FCU-011 Furnace Control Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Furnace Controller Unit serves (as the name implies) as an instrumentation and control system that interfaces with the furnace. This unit monitors the conditions associated with the furnace and is capable of controlling different aspects of the experiment associated with furnace operation. From the monitoring perspective, the FCU serves to acquire thermal information on the furnace, as well as discrete switches and positional sensors that are a part of the furnace or the sample. The FCU is designed as a reconfigurable,modular box with several standard slots, such as an Integral Power Supply, an FDMS Interface, a Processor/Memory board, and an Auxiliary Communications Slot. I/O slots include dedicated Thermocouple slots TBD channels per card, an optically isolated Discrete input card slot (TBD channels per card), and an Analog card slot with TBD differential channels, LVDT, RVDT interfaces. The motherboard for the unit is designed so that there are two different Digital Buses; one which is dedicated to the higher speed communications links between the processor and its' high speed I/Os (the FBIU & the Auxiliary Communications Slot) and another utilized for the communications with the various lower speed I/O interfaces (Thermocouples, RTD's, positional indicators, discretes, and other signals in need of conditioning or conversion).

In addition the FCU supervises a unit called the Furnace Actuator Unit (FAU) via a dedicated MIL-STD-1553 data bus on which the FCU operates as a Bus Controller, commanding and requesting status from the FAU.

Potential Uses:

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Furnace Actuator Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 22
Length (cm): 25.4
Width (cm): 38.10
Height (cm): 25.4
Power: 120
Specification ID: SSFF CEI Specification, SSFF DMS-FAU-012 Furnace Actuator Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Furnace Actuator Unit is primarily used for commanding and controlling operations of furnace activities (translation, actuation, stimulus, other various types of control etc. The FAU receives its commands from a MIL-STD-1553 link on which it is a Remote Terminal. This link is coupled to the Furnace Control Unit from which it gets its commands and to whom it sends its status and data. The FAU contains a MIL-STD-1553 serial data link, coupled with a supervisory microcontroller, and then I/O cards which include: Furnace Sample Positional Driver, a Optically-isolated Discrete Output Card with TBD channels, and Analog Voltage Card for generating fixed or variable analog signals.

Potential Uses:

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Data Acquisition System
Last Update: 4/4/92
Item Name: Distributed Core Monitor Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 10
Length (cm): 25.4
Width (cm): 24.77
Height (cm): 25.4
Power: 48
Specification ID: SSFF CEI Specification, SSFF DMS-DCMU-013 Distributed Core Monitor Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The DMCU will be a data acquisition system which will provide Input cards that monitor for the other systems in the Experiment Racks . Communication is provided in the DMCU through a 1553 link on which the DMCU is a Remote Terminal. The DMCU responds to requests for data by the CCU which supervises the operation of the other Core subsystems. The Fluids, Thermal, and Power systems will all be monitored by this system, and monitors items such as thermal conditions of other boxes to insure that other systems in the SSFF are not overheating and in thermal runaway. If this should be the case and any units are going over temperature, the DMCU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS.

These interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring, to insure that the other subsystems of the SSFF are operating properly. This will allow the Core Control Unit to perform confidence monitoring upon the other subsystems to guarantee the safe operation of the SSFF.

Potential Uses:

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

320RPT0008

SPACE STATION FURNACE FACILITY SOFTWARE SYSTEM (SSFF SW) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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Contract Number:	NAS8-38077
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SPACE STATION FURNACE FACILITY SOFTWARE SYSTEM (SSFF SW) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

Prepared By :

Advanced Programs Department
Space Programs Division
Teledyne Brown Engineering
Huntsville, AL 35807

EXECUTIVE SUMMARY

The Space Station Furnace Facility (SSFF) will be a payload for use on Space Station Freedom (SSF) for the processing of metals in a microgravity environment. The microgravity environment will be utilized to reduce the effects of convective flows around the hot/cold interface during processing of the material. This processing will produce homogeneous crystallization of materials and samples that can reveal knowledge of the materials that cannot be produced in a one gravity environment.

The SSFF will be a three-rack facility for Space Station Freedom which will be utilized for conducting experiments in the US-Lab Module A. The first rack (or Core Rack) will contain the general utilities needed by the furnaces for the processing of materials and major SSFF DMS computer services (such as SSF interface, data monitoring, processing, storage, and transmission). The other two racks, Experiment Racks 1 and 2 (ER1 and ER2), will contain the furnaces to be operated by the facility, and will be configured so that either one or both furnaces can be operated. These racks will also contain the specialized monitoring/control units and the majority of the Mission Peculiar Equipment (MPE) needed by the furnaces.

The SSFF Core Software (SW) will perform many tasks such as: hardware and software initializations, external and internal command processing, video processing functions, monitoring and controlling the SSFF Subsystem components (both core and distributed), downloading of software and data, uplink/downlink capabilities, hardware and software diagnostics/ troubleshooting and data storage and retrieval which will include database maintenance and verification. In addition to performing these tasks, the SSFF SW will include a real-time operating system, a network manager and numerous I/O libraries for internal and external communications. It will also provide external interfaces to the SSF Fiber Distributed Data Interface (FDDI), the Ground Support Equipment (GSE), the High Rate Data Link (HRDL), the Crew and the experiment unique software that will be developed independently for the actual operation of each of the furnace modules.

The components of the SSFF SW will be distributed among the Core Facility Rack and the Experiment Racks. In addition to those parts of the SSFF SW residing in the Experiment Racks, there will also be the Experiment-Specific Functions (ESF) software which will be developed separately from the SSFF SW. Whereas portions of the SSFF SW will remain relatively stable, the ESF will have to be dynamic, i.e. changed frequently, in order to accommodate addition, deletion or exchanging of experiments and furnaces.

The SSFF SW will be partitioned into Centralized Core Functions (CCF) and Distributed Core Functions (DCF). The CCF will reside on those SSFF DMS processors residing in the Core

Rack and the DCF will reside on those SSFF DMS processors residing in each of the Experiment Racks along with the ESF.

This document details the conceptual design of the Space Station Furnace Facility Software. It includes a description of the requirements, an overall SSFF SW concept, and descriptions of the individual software components necessary to perform the SSFF Software tasks.

ABBREVIATIONS AND ACRONYMS

BIT	Built In Test
CCF	Centralized Core Functions
CCOS	Centralized Core Operating System
CCU	Core Control Unit
CEI	Configuration End Item
COTS	Commercial Off-The-Shelf
CSCI	Computer Software Configuration Item
DCF	Distributed Core Functions
DCOS	Distributed Core Operating System
DMS	Data Management Subsystem
ER1	Experiment Rack 1
ER2	Experiment Rack 2
ESF	Experiment-Specific Functions
FCU	Furnace Control Unit
FDDI	Fiber Distributed Data Interface
FDIR	Fault Detection, Isolation and Recovery
GSE	Ground Support Equipment
HDR	High Density Recorder
HRDL	High Rate Data Link
I/O	Input/Output
LAN	Local Area Network
MSFC	Marshall Space Flight Center
MSU	Mass Storage Unit
NASA	National Aeronautics and Space Administration
NTSC	National Television Standard Code
RGB	Red, Green, Blue
SCRD	Science Capabilities Requirements Document
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To Be Determined

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The scope and purpose of this report is to give an overview of the Space Station Furnace Facility Software (SSFF SW) requirements and the modular design concept that meets those requirements. The report includes a description of the requirements, an overall software concept and description of the individual software functions necessary to perform the SSFF software tasks. Software areas and functions that require further analysis and/or trades to be performed are identified in Appendix A.

The task of requirements definition and design concept development was performed by the Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration (NASA).

1.2 GROUNDRULES AND ASSUMPTIONS

The following is a list of ground rules and assumptions that were used in the concept development of the SSFF SW.

1. SSFF/Ground interfaces will be handled through the interface to the SSF DMS Services and will be compatible with either the FDDI or the MIL-STD-1553 bus.
2. Specific, unique software functions are required for each configuration of experiments and furnaces and will be developed by the experiment/furnace developers.
3. This specific, unique software will be required to request all necessary services and resources from the SSFF software and will not need to interface directly with the SSF.
4. Certain software functions will be common for each configuration of experiments and furnaces and will be developed by the SSFF developers.
5. The SSFF software functions were derived from both the hardware design concepts and the Science Capabilities Requirements Document (SCRD).

2. APPLICABLE DOCUMENTS

The following documents, latest revision, form a part of this document to the extent specified herein.

Document Number	Title
SSP 30261 Rev. D 1 July 91	Architectural Control Drawing Data Management System
NAS8-38077 August 1990	DR-7 Function and Performance Specifications for Space Station Furnace Facility
JA55-032 January 1992	Space Station Furnace Facility Capability Requirements Document
MM 8075.1 January 22, 1991	MSFC Software Management and Development Requirements Manual
NSTS 1700.7B December 1991	SSFP Payload Safety Requirements, Draft

3. REQUIREMENTS

3.1 GENERAL

The SSFF SW will meet the requirements identified in the, Preliminary Contract End Item (CEI) Specifiication, Part I for Space Station Furnace Facility, the SSFF Science Capability Requirements Document (SCRD), and those requirements derived from analysis of the SSFF operations and furnace facility mission sets.

The SSFF SW will provide for the following functions: hardware and software initialization; video acquisition, processing, and distribution; command processing; monitoring and control of SSFF subsystems; downloading of software and data; uplink/downlink of data, timelines, commands, and programs; data monitoring and processing; data storage and retrieval; Fault Detection, Isolation and Recovery (FDIR) for hardware and software; real-time operating system; network management; interfacing to the SSF FDDI; interfacing with the crew (keyboard and display); interfacing with the High Rate Data Link (HRDL); interfacing with Ground Support Equipment (GSE) and interfacing the ESF software. The SSFF SW will be developed in accordance with the policies, procedures and guidelines of the MSFC Software Management and Development Requirements Manual, MM 8075.1.

3.2 INTERFACE REQUIREMENTS

This section details the external software interfaces for the SSFF SW system. Figure 3.2-1 illustrates these interfaces.

3.2.1 SSF Software Interface

The SSFF SW will provide the capabilities to communicate with the SSF for commands/services and transmission of data to ground. At the present time, the actual link is TBD; however, it will be either the SSF MIL-STD-1553 BUS or the payload Fiber Distributed Data Interface (FDDI). The SSFF communications software will conform to the appropriate protocol.

3.2.2 High Rate Data Link (HRDL) Interface

The HRDL is a physically separate interface from the interface with the SSF FDDI; therefore, it requires separate protocol software to handle the one-way transmission. The SSFF SW will provide an interface function to accommodate transfer of high rate data collected by the SSFF to the ground. This function will conform to HRDL protocols and support the HRDL format as necessary (such as the inclusion of "filler" bits into the data stream).

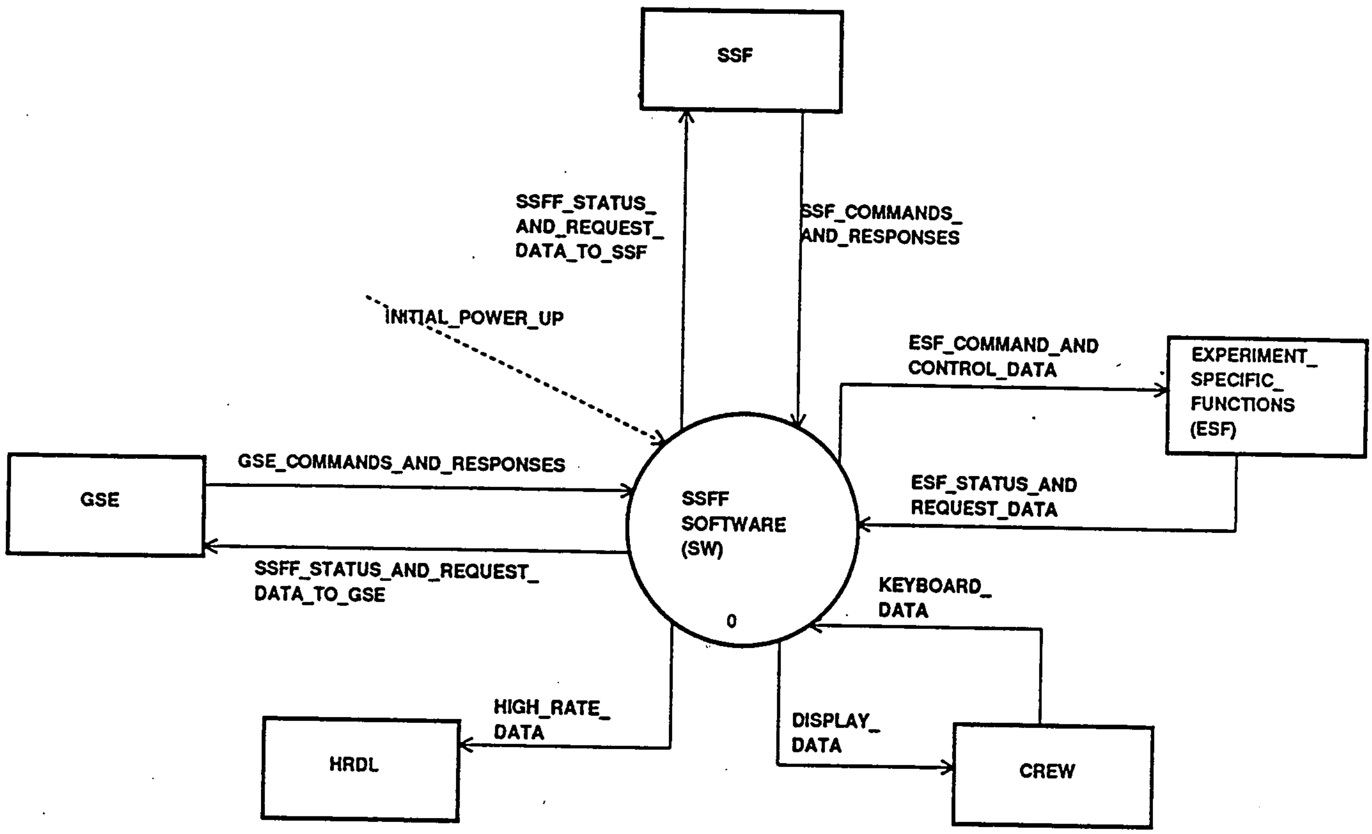

FIGURE 3.2-1 SSFF SOFTWARE EXTERNAL INTERFACES

3.2.3 Crew Interface

The SSFF SW will provide the capabilities to process keyboard and display data for receiving input from the crew and generating displays for the crew, respectively. Whenever possible, Commercial Off-The-Shelf (COTS) software will be utilized for the functionality of this interface.

3.2.4 GSE Software Interface

The SSFF SW will provide the capabilities to communicate with the Ground Support Equipment (GSE) to support ground checkout. This interface will allow the diagnostic checkout of the SSFF to be independent of the Space Station Freedom Data Management System. The software for this interface will be compatible with the protocol for bidirectional serial communications ports and FDDI for the commanding and monitoring of SSFF components.

3.2.5 Experiment-Specific Functions (ESF) Interface

The SSFF SW will be required to provide an interface to that software which will be specifically designed for the operation of each experimentor-provided furnace module. This interface will include downloading software and data to the ESF (such as timelines); collecting and processing (if necessary) data received from the ESF; responding to requests for SSFF resources such as power, gas, cooling, etc.; retrieving stored data to be output to ESF for analysis; network management of the LAN connected to the ESF processor(s); FDIR services; operating system services. The SSFF SW will also be required to interface with the following systems of the ESF: the furnace heating system, the furnace translation system (if present), the furnace cavity pressure system and the furnace current pulsing system. The interfacing to these ESF systems will involve the hardware, as well as the software, in order to provide or assist ESF hardware control and/or FDIR efforts.

4. CONCEPT DESIGN

4.1 SELECTED CONCEPT

4.1.1 General Description

The scope of this concept report deals with the functionality of the SSFF SW, i.e., what functions must the SSFF SW perform in order to support various experiment and furnace modules, rather than which functions will reside on which processors. Figure 4.1.1-1 is a high-level diagram, or component tree, of these functions. Each function in the tree could be considered a "candidate" Computer Software Configuration Item (CSCI), although the identification of CSCIs are usually reserved for the software requirements phase. As more knowledge is gained about SSFF, these functions may be easily combined or expanded into different CSCIs since, at this phase, there has been no allocation of functions to processors. This approach of delaying the allocation of functions to processors will facilitate greater flexibility and modularity of the software in the design and development phases. It also eliminates constant update of the CSCI definitions and software models if the DMS hardware should require some changes or evolve into a different configuration prior to the next developmental phase.

The SSFF SW functions will be partitioned into two groups: the Centralized Core Functions (CCF), which will reside on the processors in the Core Rack and the Distributed Core Functions (DCF), which will reside on the processors in each of the Experiment Racks. Figure 4.1.1-2 illustrates this functional partitioning along with some of the high-level data flows and software activations.

Power-up of SSFF by the Space Station Freedom will first activate the CCF processes, thus effecting an initialization process which will include self-check tests among others. After a successful initialization of CCF, then the DCF processes will be activated. Once there is a successful startup of all of the SSFF SW (and hardware), then the ESF for each furnace module present will be activated. The high level states for the software include Initialization, Standby (during which no furnaces are operating), Furnaces Operating and Shutdown. These high level states, illustrated in Figure 4.1.1-3, will be expanded and refined during the design and development phases.

4.1.2 Software Function Description

4.1.2.1 Centralized Core Functions (CCF) - The CCF will reside on the SSFF DMS processors contained in the Core Rack and will include the following functions:

1. Centralized Initialization Functions.

2. Command Processing.

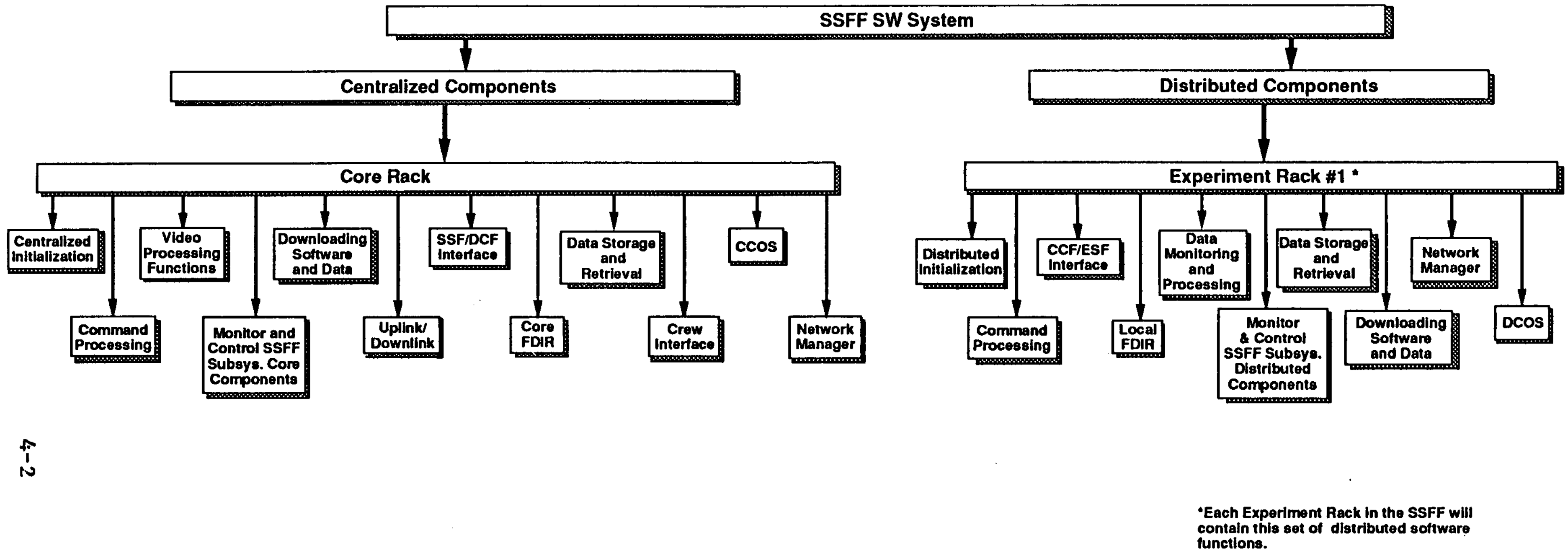

FIGURE 4.1.1-1 SSFF SOFTWARE COMPONENT TREE

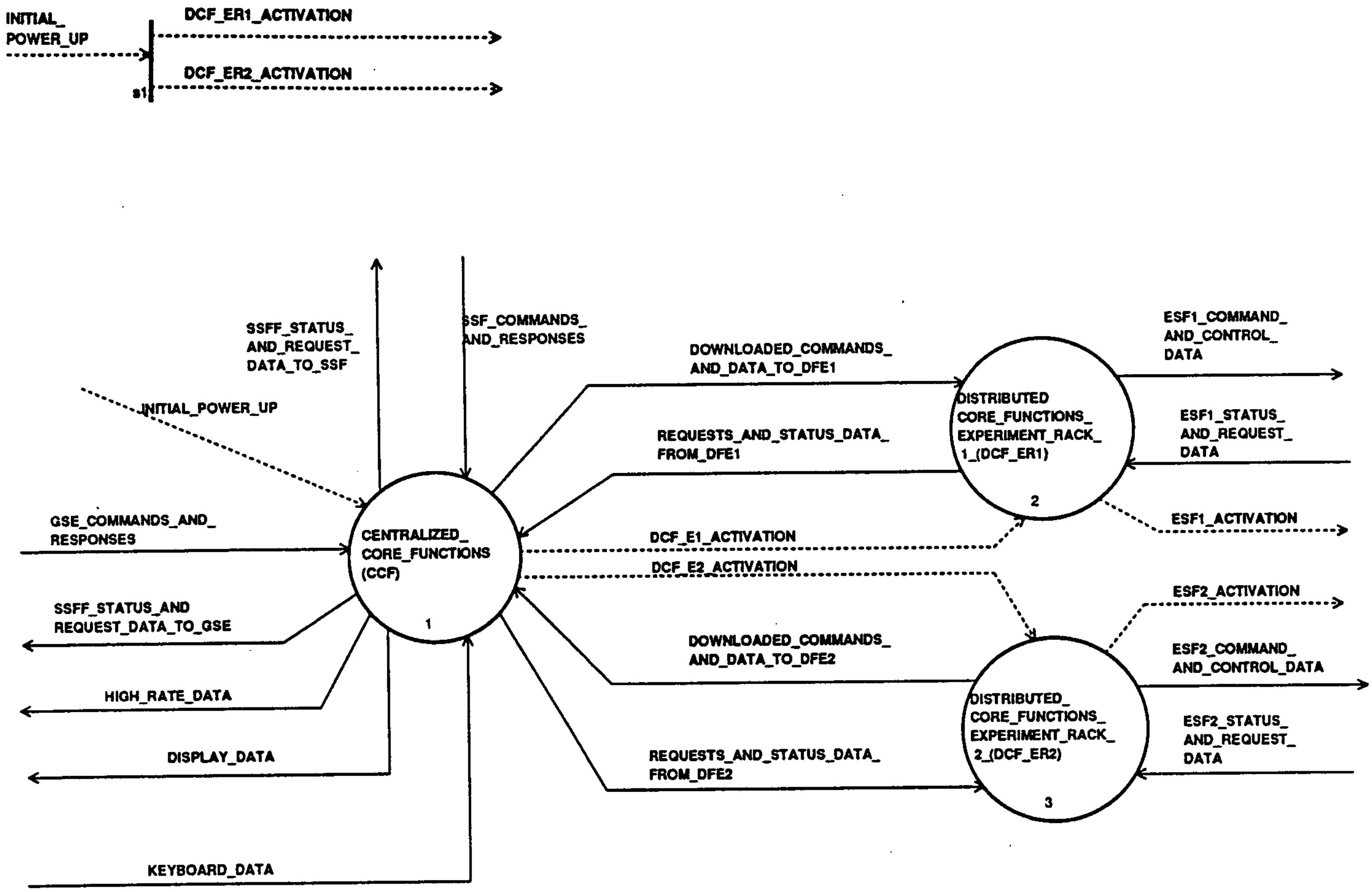

FIGURE 4.1.1-2 SSFF FUNCTIONAL DIAGRAM

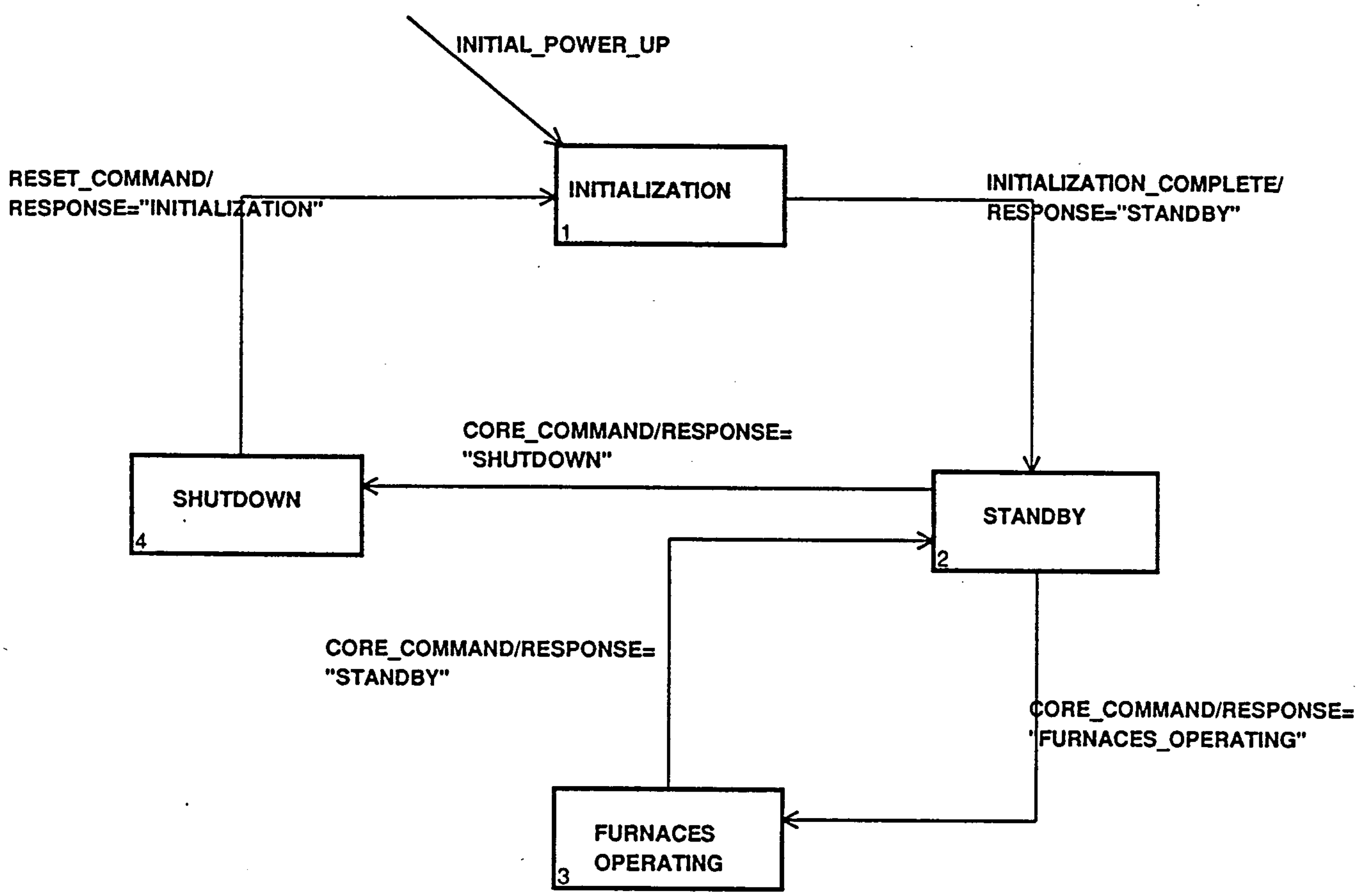

FIGURE 4.1.1-3 SSFF STATE TRANSITION DIAGRAM

3. Video Processing Functions.
4. Monitor and Control of SSFF Subsystems.
5. Downloading Software and Data.
6. Uplink/Downlink Functions.
7. SSF/DCF Interface.
8. Core FDIR.
9. Data Storage and Retrieval.
10. Crew Interface.
11. CCOS.
12. Network Manager

Each of these is discussed in the following paragraphs.

4.1.2.1.1 Centralized Initialization Functions - These functions will include an initialization of both the hardware and associated software contained in the Core Rack. The initialization process will include self-checks and Built-In-Test (BIT).

4.1.2.1.2 Command Processing - This function will receive and process commands and data coming from the SSF, GSE or the crew. This processing will include validation of commands and data, based on syntax and compatibility with a system state, and limit checking of the data. After the validation process, commands will executed or distributed to the target processor, as required.

4.1.2.1.3 Video Processing Functions - These functions will control the acquisition of RGB video data, image processing and real-time video display, support the conversion of RGB data to NTSC video format, if necessary, as well as merge non-video data with digitized video data for storage on the High Density Recorder (HDR) and/or transmission to the ground.

4.1.2.1.4 Monitor and Control SSFF Subsystem Core Components - These functions will handle receipt, processing and limit checking of analog and discrete inputs and outputs from the SSFF Subsystem Core sensors and effectors.

4.1.2.1.5 Downloading Software and Data - These functions will provide an initial bootstrap loading of the CCF software in addition to the downloading of DCF software and its associated timeline and configuration data to the SSFF processors.

4.1.2.1.6 Uplink/Downlink Functions - These functions will receive new commands and data, changes to timelines, changes to software and/or operational

parameters from the Ground through the SSF FDDI. They will also facilitate the transmission of data back down to the Ground through either the SSF FDDI or the High Rate Data Link (HRDL).

4.1.2.1.7 SSF/DCF Interface - These functions will provide the external communications to the SSF for commands and services as well as handle the internal communications of commands and data between the CCF and DCF software. These functions would provide and utilize necessary I/O libraries and device drivers for these communications.

4.1.2.1.8 Core Fault Detection, Isolation and Recovery (FDIR) - These functions will perform passive, i.e. non-disruptive, checks on hardware sensors contained in the Core Facility Rack. They will also handle the exception monitoring and diagnostics/troubleshooting for the software resident in the Core Rack.

4.1.2.1.9 Data Storage and Retrieval - These functions will create and maintain SSFF databases for storage and retrieval of all experiment data including temperature, pressure and flow rates as well as sensor data and video data. They will handle outputs to the non-volatile storage media and inputs from the high density storage device. They will provide database maintenance, verification and configuration control for the CCF data.

4.1.2.1.10 Centralized Core Operating System(CCOS) - This function will provide real-time operating system for each of the main processors contained in the Core Rack.

4.1.2.1.11 Network Manager - This function will provide network management of the LANs connected to the CCF processors.

4.1.2.2 Distributed Core Functions (DCF) - Each Experiment Rack will contain a common set of DCF. The DCF will include the following functions:

1. Distributed Initialization Functions.
2. Command processing.
3. CCF/ESF Interface.
4. Local FDIR.
5. Data Monitoring and Processing.
6. Monitor and Control SSFF Subsystem Distributed Components.
7. Data Storage and Retrieval.
8. Downloading Software and Data.

9. Network Manager.

10. DCOS.

Each of these is discussed in the following paragraphs.

4.1.2.2.1 Distributed Initialization Functions - After the CCF have successfully completed the centralized initialization process and the DCF have been activated, then an initialization process for both the distributed hardware and associated software contained in each Experiment Rack will be executed, one rack at a time. This initialization process will also include self-checks and BIT, similar to the centralized initialization process.

4.1.2.2.2 CCF Command Processing - This function will receive and process commands and data coming from the CCF and ESF software and will issue commands or responses to commands, if necessary, to the ESF. Processing will include validation of commands and data and limit checking.

4.1.2.2.3 CCF/ESF Interface - These functions will handle internal communication of commands, data and services between the DCF and CCF software and between the DCF and ESF software. In addition, these functions will coordinate resource requests from the ESF software with the CCF software. These functions would provide and utilize necessary I/O libraries and device drivers to accomplish these communications.

4.1.2.2.4 Local Fault Detection, Isolation and Recovery (FDIR) - These functions will perform passive (non-destructive) checks on the hardware sensors local to the Experiment Racks. They will also handle the exception monitoring and diagnostics/ troubleshooting for the software resident in the Experiment Racks.

4.1.2.2.5 Data Monitoring and Processing - These functions will handle collection and limit checking of experiment data from the ESF along with the transmission of this data to the CCF for further processing, storage or downlinking. If necessary, these functions would pre-process the data before transmitting it to the CCF or to the DCF Data Storage and Retrieval function.

4.1.2.2.6 Monitor and Control SSFF Subsystem Distributed Components - These functions will handle receipt, processing and limit checking of analog and discrete inputs and outputs from the SSFF Subsystem Distributed sensors and effectors.

4.1.2.2.7 Data Storage and Retrieval - These functions will create and maintain limited, local databases for storage and retrieval of experiment data including temperature, pressure and flow rates as well as sensor data and video data. This storage would be temporary until it is transmitted to the CCF for permanent storage or transmission to the ground or SSF. These functions will provide the maintenance, verification and configuration control for the local databases.

4.1.2.2.8 Downloading Software and Data - These functions will provide a bootstrap loading of DCF and ESF software and downloading of timeline and reconfiguration data to the ESF software residing in the Experiment Racks.

4.1.2.2.9 Network Manager - This function will provide network management of traffic on the LANs connected to the CCF and DSF processors.

4.1.2.2.10 Distributed Core Operating System (DCOS) - This function will provide a multi-tasking operating system for each of the SSFF-provided main processors contained in each of the Experiment Racks.

4.2 SAFETY

Any software requirements that have been identified as hazardous or resulting in hazardous conditions shall meet the SSFP Payload Safety Requirements, NSTS 1700.7B Addendum 1.

5. RESOURCE REQUIREMENTS

The memory resource requirements for the SSFF software are currently estimated at 200 Megabytes.

6. ISSUES AND CONCERNS

To date, no significant issues and concerns have been identified for the SSFF software development except for the unclear definition of the SSF DMS interfaces. The SSFF team will continue to monitor and collect any information available on the SSF DMS.

320RPT0008

SPACE STATION FURNACE FACILITY GAS DISTRIBUTION SUBSYSTEM (SSFF GDS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

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SPACE STATION FURNACE FACILITY GAS DISTRIBUTION SUBSYSTEM (SSFF GDS) CONCEPTUAL DESIGN REPORT

April 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
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EXECUTIVE SUMMARY

The purpose of the Gas Distribution Subsystem (GDS) is to provide the distribution of SSF provided gases and vacuum to the furnace modules. It also provides contamination monitoring of waste gases, and gaseous argon to the furnace modules. The GDS interfaces with the SSF Lab Nitrogen System (LNS) and the Vacuum Exhaust System (VES). GDS interfaces with the furnace modules will be the nitrogen, vacuum, argon, and contamination monitoring interfaces.

Presently, the SSF VES has imposed tight restrictions on the levels of allowable contaminants for vent products. The need exists to vent or store the waste gases in order to properly operate* furnaces. Three options to implement this function were considered. One would be to compress waste gases and store them at high pressures when contaminant levels were exceeded. This method is presently not possible (no compressors exist to perform this function). Another option would use an available compressor but the compression ratio is not high enough (would require too large a volume for storing of the gases). Another option would use a filtering system in conjunction with a contamination monitoring system to determine when contaminant levels exceeded acceptable limits. This concept relies on the acceptance of contaminant levels of waste gases under normal furnace operation. Should an ampoule break the containment of the contamination to a small area is possible by sealing and shutting down the furnace.

Problems associated with controlling the pressure have surfaced recently. In order to actively control the pressure in the furnace module a dedicated vent line or the ability to store some gases needs to be provided to the furnace module. Since SSF does not allow "at will" access to the vent line the most reasonable solution to this problem is to use a compressor and storage bottle to properly control the pressure. Other possible methods that would not impact the furnace modules as much are being investigated. Should one of these prove to be a viable solution it would be incorporated into the GDS concept.

Based on the difficulties associated with trying to compress and store waste gases the option requiring no storage of waste gases is the one presented in this report. Preliminary calculations for resource requirements show a mass of approximately 165 kg and power requirement of 75 Watts. The bulk of this power is needed for the contamination monitoring system. For this Non-Dispersive Infrared Spectroscopy and X-Ray Fluorescence units were used as placeholders.

*These options operate with the premise that waste gases will only be vented under normal furnace operation. Abnormal operation is when an ampoule breaks (or leaks), contaminating the furnace chamber.

The main concerns of GDS are the active control of the pressure and the allowable vent products accepted by SSF VES. By performing extensive testing and analysis of waste gases for ground based furnaces it may be possible to show that furnace vent products will not exceed the contamination limits of SSF. If this were to happen the need for a CMS would be eliminated, freeing valuable space needed in the core rack. The active control of pressure also impacts the design of the GDS. Eliminating the requirement for active control during processing would simplify the design of the GDS making room for other components in the furnace racks.

ABBREVIATIONS AND ACRONYMS

AADSF	Advanced Automated Directional Solidification Furnace
CCU	Core Control Computer
CGF	Crystal Growth Furnace
DMS	Data Management Subsystem
GDS	Gas Distribution Subsystem
GN2	Gaseous Nitrogen
LNS	Lab Nitrogen System
MTC	Man Tended Capability
NDIR	Non-Dispersive Infrared
ORU	Orbital Replaceable Unit
PCDS	Power Conditioning and Distribution Subsystem
PMC	Permanently Manned Capability
QD	Quick Disconnect
SSFF	Space Station Furnace Facility
SSF	Space Station Freedom
TCS	Thermal Control Subsystem
VES	Vacuum Exhaust System
XRF	X-Ray Fluorescence

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The intention of this report is to provide a description of the conceptual design for the GDS of the SSFF. It is part of a research study entitled "Space Station Furnace Facility". The analyses and investigations presented are intended to fulfill paragraph 5.1.1 of the Statement of Work. This concept is an update from that presented at the SSFF 5th quarterly review held June 27, 1991. The work was done by Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration.

The SSFF consists of a core rack which will provide a set of standard support services to one or more furnace modules. The facility is presently configured to operate with two separate furnace modules. The variety of furnaces which could operate with the SSFF core rack will demand adaptability in the core to provide the resources needed to operate each type of furnace.

The SSFF GDS will provide an interface to the SSF Lab Nitrogen System (LNS) and Vacuum Exhaust System (VES). The GN2 will be used as a purge gas to clean the furnace container while the vacuum vent line will be used to vent the furnace gases. The GDS will also provide argon as a process gas. The argon will be provided as an ORU and can be replaced by other desirable process gases.

1.2 GROUNDRULES AND ASSUMPTIONS

The following ground rules and assumptions represent PMC for volume estimates and MTC for control and operation.

1. The two furnace enclosures are assumed to have volumes of 708 liters each (25 cu.ft.- roughly the same size as CGF). This does not include the volume reduction for equipment internal to the furnace enclosure.

2 Samples will not be launched in the furnace and will be loaded on orbit.

3. It is assumed that two sample carousels will be processed during a 90 day mission at PMC, requiring a total of four separate purge cycles. Purging is required before the first carousel is processed before removing the first set of samples, after loading the second carousel, and before the second carousel is harvested by the resupply flight.

4. Purging will involve filling the furnace enclosure with nitrogen two (2) times to approximately 82.4 kPa (12 psia) to remove moisture and oxygen. The enclosure contents (air/nitrogen/waste gases) are vented to the vacuum system (if clean). After the two initial nitrogen purge cycles, the enclosure is back-filled with argon once to approximately 68.7 kPa (10 psia) for processing three samples. After the third sample the enclosure will be evacuated and purged with nitrogen and backfilled with Argon for the remaining three samples. After carousel is completely processed it will be assumed two more nitrogen purges will be made to sweep the enclosure before sample removal.

Note: The processing pressure can rise about 13.74 kPa (2 psia) with the enclosure at 50°C (touch temp). The minimum pressure currently required for CGF is 0.69 kPa (0.1 psia). Since the SSF Cabin Environment may be at 70 kPa (10.2 psia) minimum, the SSFF backfill pressure will always be at least 13.74 kPa (2 psia) less. However, for sizing calculations, 82.4 kPa (12 psia) will be used as worst case to bracket the maximum argon or nitrogen requirement.

5. Argon will be assumed to be the primary processing atmosphere, with nitrogen from SSF used as a purge gas to remove moisture and oxygen from the furnaces between sample loadings.

6. Argon will be stored in ORU gas supply bottles having .94 cu.ft. (26.73 liters) of storage volume each and weighing 13.6 kg (29.9 lbs) /bottle empty.

7. It is assumed that bottle storage pressure will be 20,713 kPa (3014.7 psia) at 25°C, (assuming any safety concerns over use of this high pressure can be satisfied).

8. At this time it will be assumed that furnace products can be vented to SSF, after analysis of the contents for acceptance within the contamination limits.

2. REQUIREMENTS

2.1 GENERAL

The SSFF GDS shall meet the requirements identified in documents DR-7, Function and Performance Specifications for Space Station Furnace Facility and the Capability Requirements Document and those requirements derived from analysis of the SSFF operation and furnace facility mission sets.

2.2 GDS INTERFACE REQUIREMENTS

The SSFF GDS shall interface with the SSF and other SSFF subsystems. The following sections describe these interfaces. Figure 2-1 Illustrates the interfaces of SSFF with the SSF and the furnace modules.

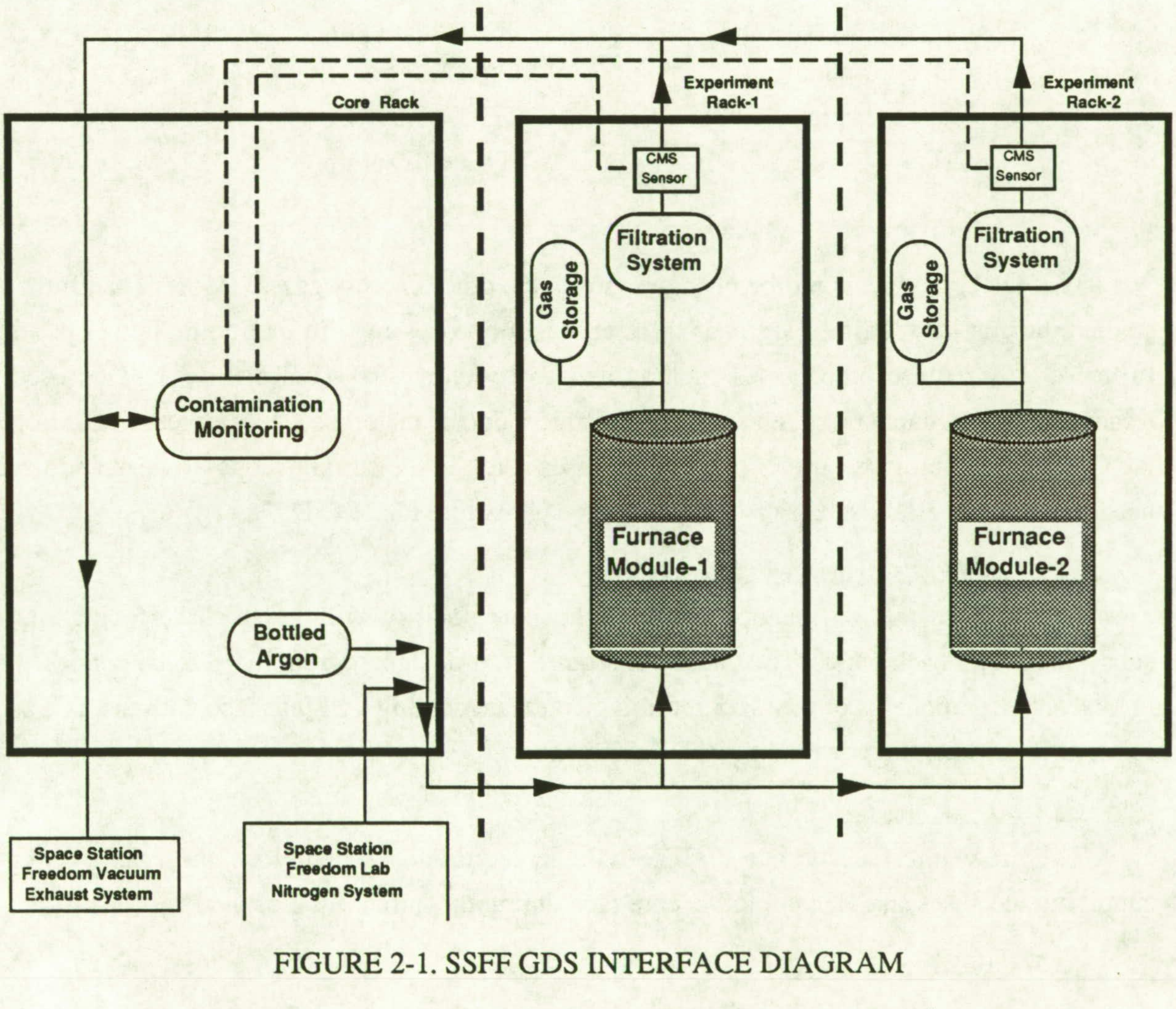


FIGURE 2-1. SSFF GDS INTERFACE DIAGRAM

2.2.1 SSF GDS Interface

Space Station Freedom (SSF) will provide dry nitrogen to the core rack at 618-756 kPa (90-110 psia). The gaseous nitrogen supplied to SSFF from the Space Station is specified in MIL-P-27401C as: Type I (gaseous), Grade C (99.995% pure). This is regulated down internally in the core to approximately 137-240 kPa (20-35 psia) for safe pressurization of the furnace enclosures. 6.35 mm (1/4") lines will be used to supply gas (nitrogen and argon) throughout the facility. SSF will also provide a vacuum line interface to the core rack which furnishes the furnace modules access to the 1×10^{-3} Torr vacuum through a 2.54 cm (1") dia. line.

2.2.2 SSFF GDS Furnace Module Interface

Argon, used as a process gas, will be provided by an ORU module in the core rack. The supplied argon will be research grade having the following contaminant levels:

99.9995 % pure	$N_2 < 3.0$ ppm
$CO_2 < 0.5$ ppm	$N_2O < 0.1$ ppm
$CO < 1.0$ ppm	$O_2 < 1.0$ ppm
$H_2 < 1.0$ ppm	THC < 0.5 ppm
$CH_4 < 0.5$ ppm	$H_2O < 0.5$ ppm
	dew point = -112°F

This ORU module could be changed to provide other process gases. Most of the furnaces studied thus far have utilized argon as the inert gas for processing. In the future, however, some furnaces may require other gases such as helium or hydrogen. Hydrogen would be used to remove trace amounts of oxygen from some semiconductor materials. A complete evaluation of the GDS compatibility for use of these other gases is not in the current scope of work and would need to be firmly established as a design requirement before Phase C/D.

2.2.3 SSFF GDS Subsystems Interface

An integral part of the operation of the core facility will be the interfacing of the subsystems with each other. The GDS will require control signals from DMS to be connected to the valves. Components of the GDS requiring coldplate cooling will interface with the TCS, and PCDS will provide the power to the GDS components.

2.2.4 Crew Interface

The crew interface with the GDS will be required to open/close the manual valves supplying the gases and vacuum to the core rack during the initial setup of the facility.

2.2.5 GSE Interface

TBD.

3. CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

Several options are currently under study for the design of the waste gas vent system. One of the options is for a specialized waste gas analysis and storage system to be placed in the core rack of the SSFF. This system might be required, since the acceptability of the furnace vent products to the SSF requirements has not yet been fully established. In this system a contamination monitoring system would be utilized to provide analysis of the process gases to facilitate an active two way processing decision; i.e., OK to vent or have the GDS compress and store the gas products. Though this option would be an ideal operating mode, technological (a compressor required for this purpose would consist of many stages, making it massive and power hungry) and logistical problems prevent it from being an economical or fully viable solution.

Another possible option for the vent system would use filters and a contamination monitoring system which could reliably detect and safely remove (if possible) the hazardous or unacceptable vent products. Figure 3-1 illustrates this concept. The design is based on the assumption that venting to the VES is possible under normal furnace operation. Products from a ruptured experiment ampoule could not be vented nor should the astronauts be exposed to the hazardous products. At this time the GDS is not responsible for detecting a ruptured ampoule, however it would react to notification of such an event by shutting down operations, locking out a vent command, and sealing the furnace for the remainder of the mission. If this situation occurs the astronauts would remove the contaminated furnace and transport it back to Earth for decontamination. Possible contamination products would include, but are not limited to: moisture, particulates, hydrocarbons, and other trace gases which might react with or degrade the SSF vent line. Ascertaining the complete nature of a filtration system design requires more study and data collection on the vent product composition from a number of furnaces. With this data a more comprehensive analysis and search can be made for filtration materials, which could effectively neutralize the products to SSF acceptable limits.

A third option would rely on testing and data generated on the vent products of furnaces. Ideally the furnaces would go through a lengthy check out procedure to "prove" that the waste gases are safe to vent to station. This option would require an extensive amount of testing and data analysis of the furnaces that would be on SSFF. Provided all of the candidate furnaces check out for off gassing of contaminants this design would prove to be simple and the easiest to implement.

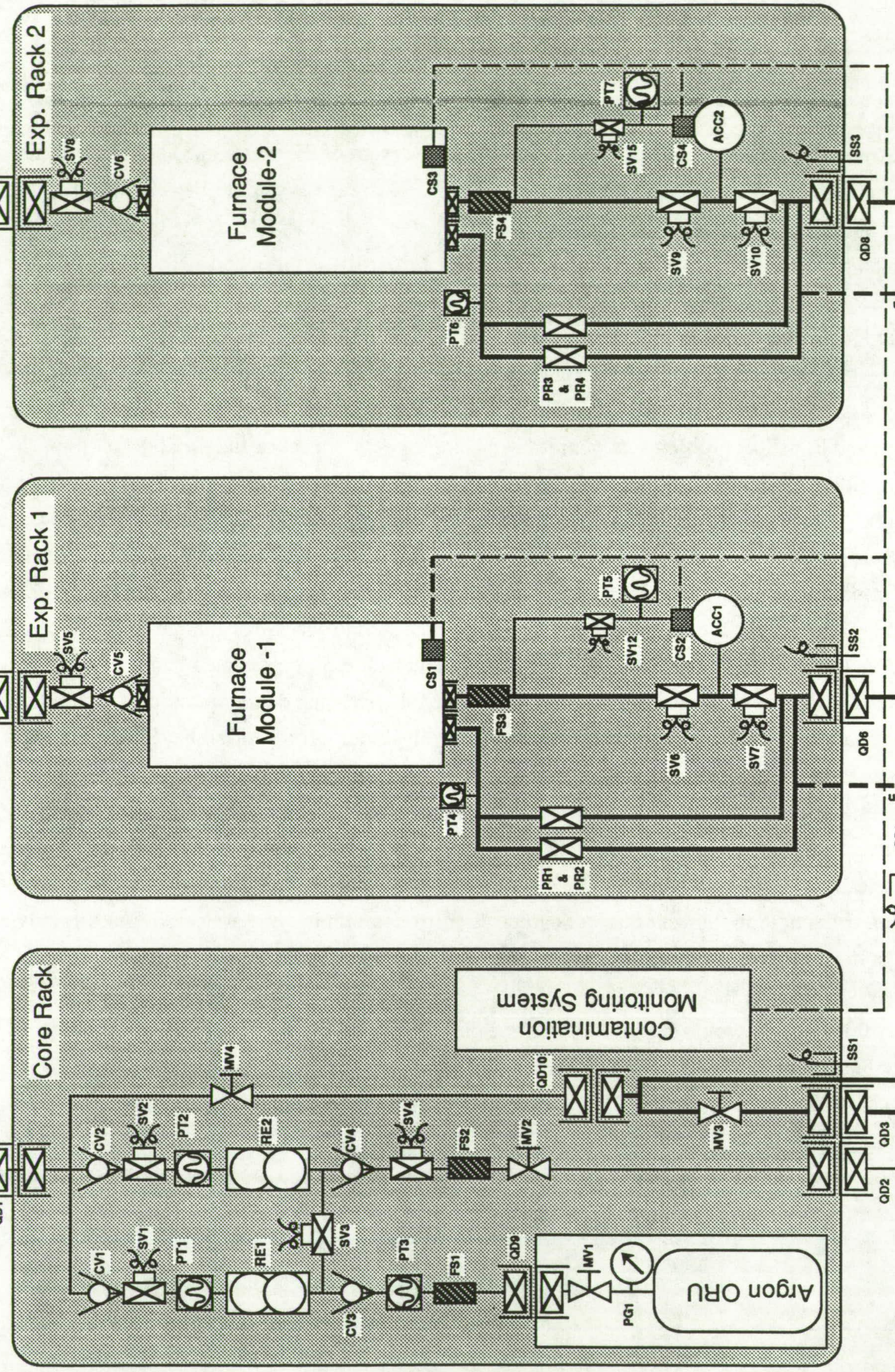


Figure 3-1. Gas Distribution Schematic

3.2 SELECTED CONCEPT

Problems associated with compressing and storing of contaminated gas from furnaces rule out the first concept. The third option would be difficult to implement due to the large number of furnaces that would need to be considered. The selected concept for the GDS is the second one. It involves the analysis of waste gases and vents or seals the furnace depending on the contaminant levels.

3.2.1 System Operation

The SSFF consists of a Core Rack which will provide a set of standardized support services to one or more furnace modules. At this time, the facility is being configured to operate with two separate furnace modules. The variety of furnaces, which could operate with the SSFF core, demand adaptability of the core to provide the resources needed to operate each furnace. In the GDS, this adaptability is provided by distributing elements of the system hardware between the core and experiment racks, and by making the elements in the core as flexible as possible for reconfiguration, maintenance, and upgrading (as required).

Currently, the GDS is configured to automatically regulate and control the flow of either nitrogen or argon as a purge or process gas using the DMS CCU (see the DMS Concept Description for clarification of the CCU function and performance).

The preliminary conceptual design for the GDS can be broken into three basic elements for discussion: the Core Rack Gas Supply, the Experiment Rack Provided Components, and the Core Rack Vacuum/Vent System. The final design of the GDS will depend on the outcome of several safety and hardware related issues which must be resolved with the users and Work Package 1.

Though some experiments performed within SSFF may contain hazardous materials such as mercury, beryllia, and arsenide, etc., the analyses of venting products made to date indicate trace contamination levels are relatively benign (unless an ampoule has broken). The present tight contamination concentration limits permitted by SSF in the vent products will require SSFF to analyze the gas content and process (filter and neutralize) all gases/materials not within specification. The high risk development technology associated with these type hardware items would not be necessary, if the concerns over contamination of the vent products (except in the case of ampoule rupture) could be eliminated. TBE has developed a preliminary data base on vent products collected from CGF and the AADSF furnaces during some laboratory runs. Plans are also in work to collect vent line analyses from several SpaceLab missions to add to the data base. If this compilation of data continues to show relatively clean results, then the complexity of the vent gas processing equipment can be greatly reduced.

As shown in Figure 3-1, the GDS will interface directly with the SSF Gaseous Nitrogen Supply line, and the VES through QD's located on the utility interface panel. The rack interconnect supply lines (gas and vacuum), with QD's on either end, run in a tray assembly on top of the stand off. The tray holds the lines in a prescribed orientation to insure organized routing from the core rack interface plate to vertical interface panels on the two furnace racks. The tray will also insure the lines do not become entangled (during rotation) and prevent each rack from being folded out in 60 seconds for emergency access to the Lab shell.

3.2.1.1 Gas Distribution - SSFF will provide an interface to the SSF Lab Nitrogen System (LNS) to be used as a purge gas. A process gas, such as argon, will also be provided to the furnace modules. Appendix A contains the assumptions and the sizing calculations of the argon storage system and quantity of nitrogen required from SSF.

3.2.1.2 Filter System - An integral part of a successful gas distribution system would include a filter system enabling the furnace to vent waste gases to SSF. In the technical report "Space Station Furnace Facility Venting Requirements Task" (SSFF-VTR-001) written by Teledyne Brown a four stage filter system was described that might be used by the GDS to clean up waste gases generated by the furnaces. The following is from that report.

The proposed SSFF Filter system would likely involve multiple stages of various components with different design functions. For example:

- Stage 1 could be a particulate filter to prevent furnace materials and dust from passing into the SSF vacuum vent system.
- Stage 2 could be a cold trap which would prevent metal and other low vapor pressure substances from further progress into the venting system.
- Stage 3 could be an adsorption system using granular activated charcoal. This would provide a wide spectrum adsorption capability to minimize the passage of normal furnace out-gassing materials such as cleaning solvents and lubricants.
- Stage 4 could be a special application filter stage designed to absorb or neutralize known hazardous materials in the samples being processed. This stage might have several different internal designs using different active agents but all using the same SSFF interface attachments. Mission specialists might install specific filter components depending on the samples being processed by the SSFF. For example, a special mercury adsorption compound could be installed before the processing of HgCdTe samples. The next PI might have a GaAs sample which would require astronauts to change out the activated filter for an arsenic neutralizing compound.

The various stages of the SSFF Filter System do not have to coexist within the SSFF rack. It makes more sense for stages 1, 2, and possibly 4 to mounted directly on the individual SSFF furnace experiment containers. The cold trap could use a branch of the furnace water cooling water for its active temperature control. The particulate filter could be installed at the vent port

of the furnace container, where the crew could inspect and change it easily. The special absorption filter might be installed either at the furnace or within the SSFF. Mounting pre-filters at the furnace rack could minimize contamination of the interrack vent lines. Since stage 3 is a general generic all purpose filter it could be installed within the SSFF rack. All of these gas treatment devices would require occasional change-out by the crew.

The different stages of the filter system would not have to be located within the SSFF rack. Stages 1, 2, and 4 could be mounted on the furnace module. Stage 3 would be the only one required to reside with the rack equipment. However all stages would require changeout by the crew after they were no longer effective.

3.2.1.3 <u>Vacuum Vent System</u> - The core rack vacuum system consists of the plumbing and control components which vent furnace products to the SSF VES. There is also a vent line on the gas supply which connects within the core rack to the vacuum system for maintenance and system shutdown operations.

3.2.1.4 <u>Furnace Pressure Control</u> - In order to perform active control of the gas pressure inside the furnace module (as specified in the Science Capabilities Requirements Document) access to a dedicated vacuum line would need to be available at anytime during sample processing to remove excess gas as the pressure inside the furnace module increases. Since this is not possible (due to contamination concerns of the of the vent line and scheduling) other possible options need to be considered. Two options being considered will be described in the following sections.

3.2.1.4.1 <u>Compressed Gas Storage</u> - As the temperature of the process gas rises the pressure will increase. To compensate for this a compressor (pressure control vacuum pump) would be used to store any excess gas in a storage bottle. Figure 3-2 illustrates this option. Limited availability of volume in the Experiment Racks will severely limit the size of storage bottle and compressor that could be used with this option. A realistic compressor that might be used in this application would only allow for a maximum pressure differential of 90 psi in a .94 ft^3 storage bottle. This could allow for 2-3 psi fluctuations within the furnace module.

3.2.1.4.2 <u>Constant Temperature Gas</u> - Pressure rise of the process gas is related to increasing temperature inside the furnace module. Another possible option to control the pressure would be to control the gas temperature (constant temperature = constant pressure). A water to gas (argon) heat exchanger would be located inside the furnace module with a fan to control flow of gas over the heat exchanger. Provided the heat exchanger could effectively remove any heat added to the gas, the pressure inside would remain constant. To act as a buffer for this option a storage bottle and pressure relief valve would be connected to the furnace

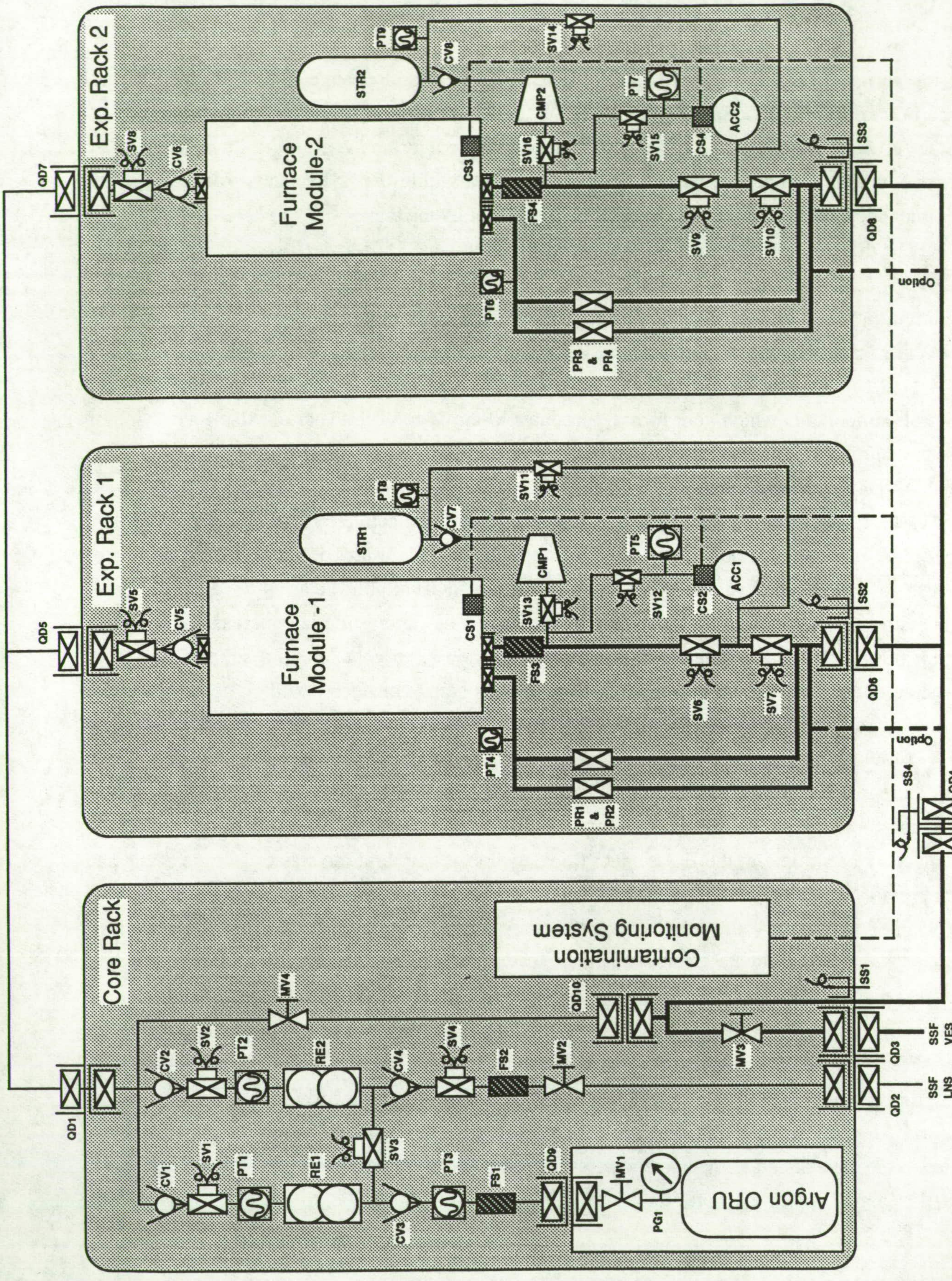


Figure 3-2. GDS schematic with compressor controlled pressure option

module. The pressure relief valve would let gas into the storage bottle if the pressure began to rise. Figure 3-3 is an illustration of this concept. As stated with the previous option only small fluctuations in pressure could be handled.

3.2.1.4.3 Selected Pressure Control - The option of controlling the pressure by controlling the temperature has not been completely investigated. Therefor this report will follow the compressed gas option to control the pressure. The temperature control process will continue to be investigated. If it proves to be a feasible approach for pressure control it will replace the compressor option.

3.2.2 System Operation

The core rack gas supply can be seen (Figure 3-2) to have two separately regulated gas supply loops. The first one starts at the argon ORU module. It consists of a structural frame sized to fit in a logistics tray slot 26.7x45x76.2 cm (10.5 h x 17.75 w x 30 d). The frame holds the gas storage bottle and has a face plate which mounts to a manual bottle outlet valve and a bottle pressure gauge. The frame is designed to align the gas supply QD with the core rack mating half when the tray is inserted and locked into place. Figure 3-4 illustrates the argon ORU concept. Gas would flow from this module through the gas control assembly ORU. The gas control assembly filters and regulates (from 3000 to 20-35 psia) the gas. The supply and regulator outlet pressures are both sensed by transducers which feed the Core Control Unit (CCU) computer and are also displayed visually on the operator's panel. The argon can be released to the furnace block valve by latching solenoid valve SV1.

Nitrogen enters the core rack from the station feed at 618-756 kPa (90-110 psia) and passes through a manual shutoff valve, filter, latching solenoid valve, and regulator. The pressure in the station system should be available from the Station DMS, while the regulator outlet setting is also fed to the CCU and read out visually. The SV2 block valve releases nitrogen to the furnace rack. Only one gas supply system is expected to be open at a time (nitrogen or argon); however, through the use of check valves and a cross over valve (SV3) the two systems can be cross connected under certain conditions should either regulator fail.

The VES line (Figure 3-2) connected to the furnace will only have two solenoid valves (SV6, SV7) and one filter (FS3) to keep the flow of exhaust gases as unobstructed as possible. The Contamination Monitoring System is presently using two separate techniques for analyzing exhaust gases. An X-ray Fluorescence (XRF) system to detect possible metal vapors and a Non-Dispersive Infra-Red (NDIR) system to analyze gas quality. The XRF will use a sensor located in the furnace module (CS1) while the NDIR will branch off from the main VES line to check gas sample quality (CS2).

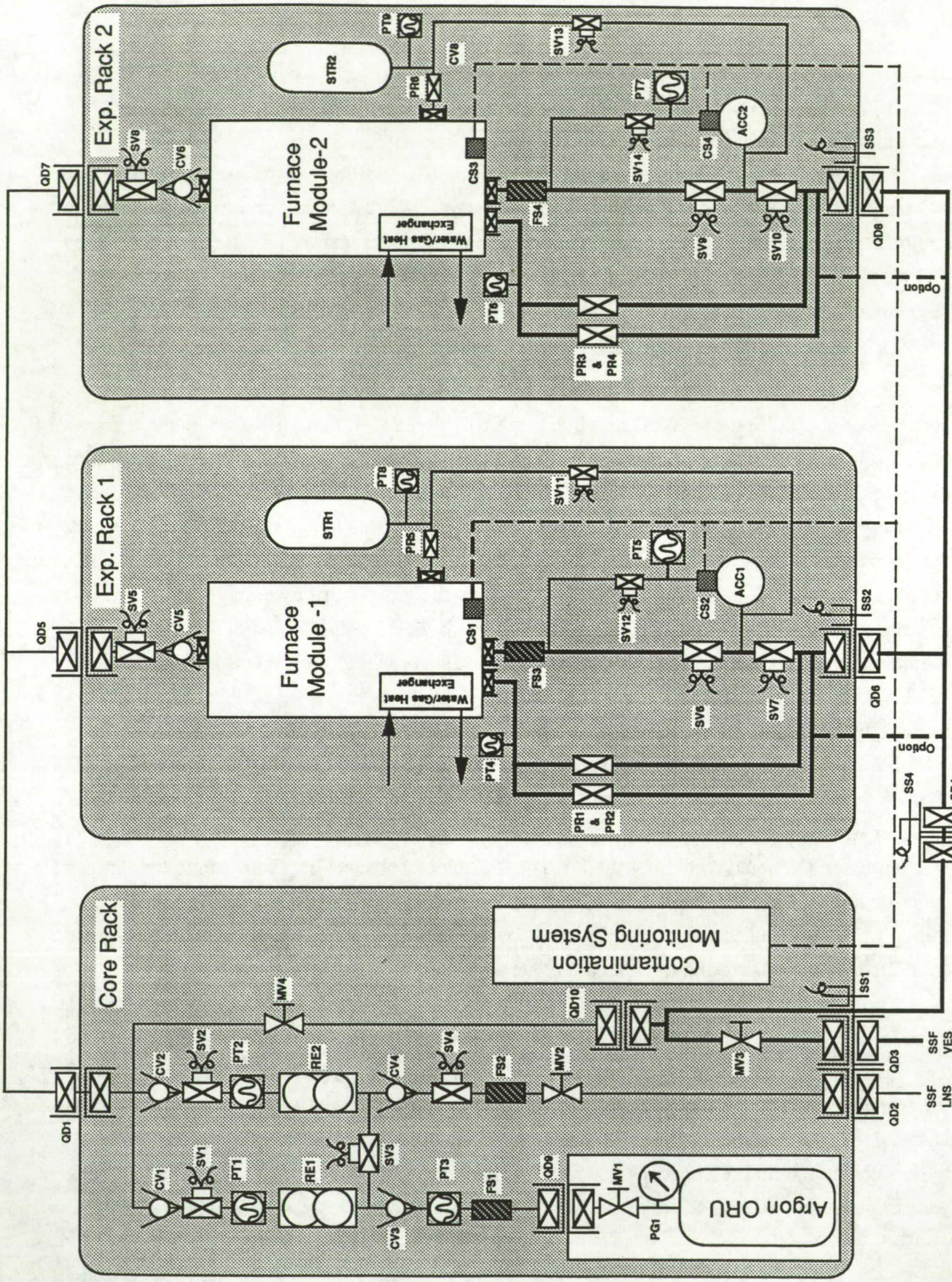
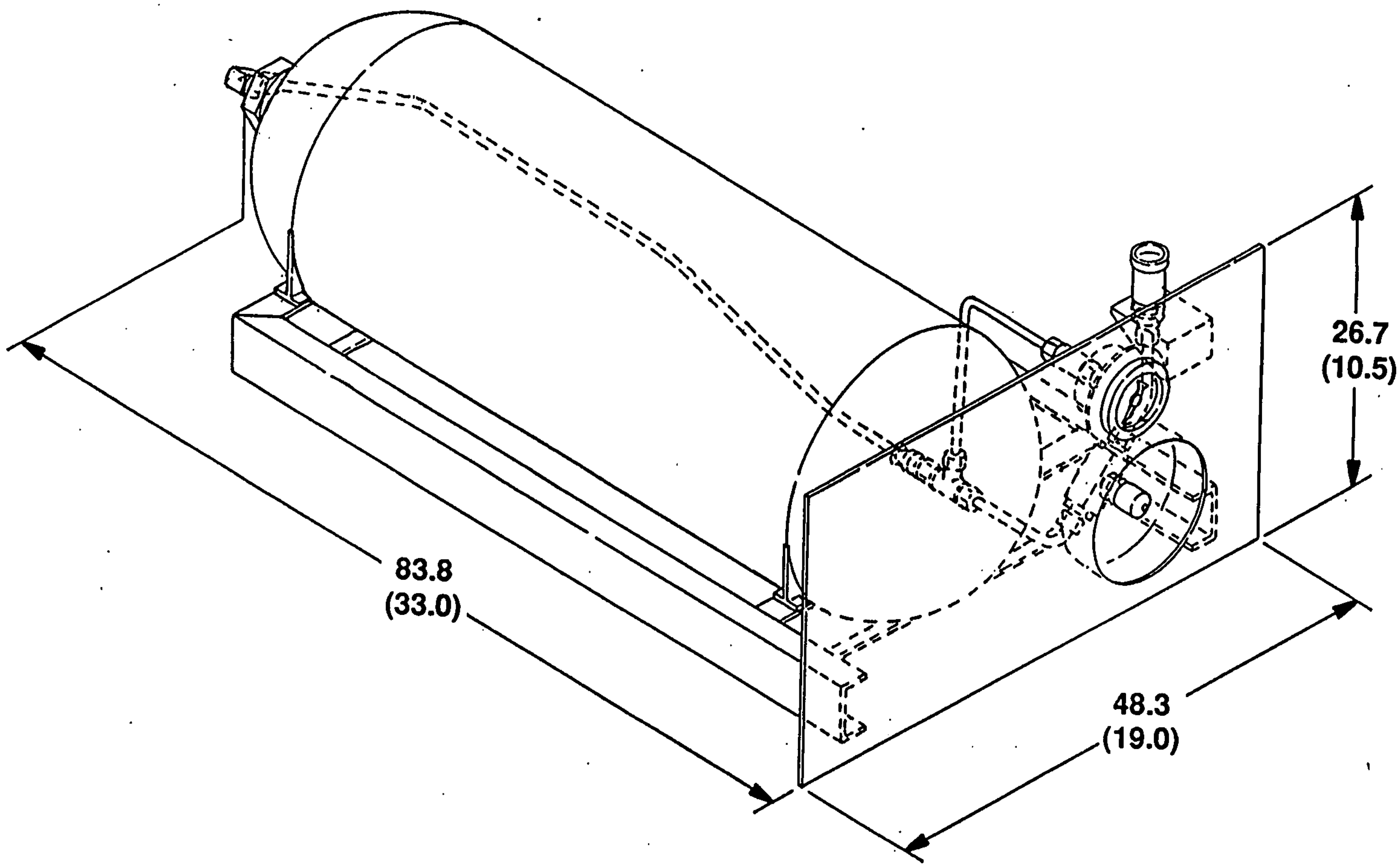


Figure 3-3. GDS schematic with temperature controlled pressure



NOTE: DIMENSIONS IN CENTIMETERS (In.)

Figure 3-4. Gas Supply Module: processing gas supply for the furnace modules. Holds 19.5 lb of Argon at 20684 kPa. Uses quick disconnects for connecting to Gas Supply ORU. Line size: 6.35 mm dia. Mass: 22.5 kg.

3.2.2.1 <u>GDS Components</u> - The core rack contains the majority of the components of the GDS. Table 3-1 lists the GDS components located in the core and the salient characteristics of each. Figure 3-5 shows the ORU breakdown and the components they contain. Figure 3-6 through 3-11 illustrate how some of the components would look. Figures 3-12 &13 show how the GDS components would look when installed in the SSFF racks.

In the plumbed portions of the GDS, gases flow through 6.35 mm O.D. stainless steel tubing of 0.71 mm wall thickness. The gas will flow through at least a 5 micron nominal size filter and check valve when entering the system. The filter is used to remove any particulates that may cause damage to downstream components, specifically pressure regulators.

Purge or process gas coming from the core rack to the furnace rack will encounter a normally closed solenoid valve which must be energized and held open for pressure to reach the enclosure. The furnace pressurization is controlled by the CCU computer using pressure feedback data processed by the Furnace Control Unit (FCU) from sensors on the furnace (PT4 or 6). The block valves (SV5 or 8) are cycled as required to achieve the desired pressure. A purge cycle will always follow a vacuum cycle, where the enclosure has been evacuated by the vent line through SV7 or 10. Vacuum levels will be monitored by transducers, PT1/9 or 3/10, and the data provided to the CCU for control of the pump and valves.

For safety reasons, pressure relief valves are required to be provided with the furnace module. The schematic shows redundant pairs (PR1&2, PR3&4) which are to be set at the required relief setting based on the particular structural strength of the furnace enclosure. Because of concerns over hazardous contaminations in the vent products, the relief valves have to be tied into the vacuum vent line, which returns to the core rack. Whenever conditions exist that could cause the furnace enclosure to be over pressurized (i.e. during pressurization or in certain heat up conditions) the vent line will be configured (through PR1-4) to give a relief path to the SSF vacuum exhaust system.

3.3 SAFETY CONCERNS

The GDS conceptual design presents several significant safety concerns for the SSF and its crew. Some of the more hazardous safety issues associated with the GDS design include:

- Use of high pressure gasses with the potential for explosive rupture with fragments. Typical hazard control measures for high pressure systems include designing pressure vessels to MIL-STD-1522A which requires applications of fracture control techniques. Lines and fittings will be designed to appropriate safety factors of 2.5 ultimate based on the system maximum design pressure (MDP). When regulators, relief valves, etc., are used to determine MDP, the system will have a level of failure tolerance appropriate to the hazard classification level.

TABLE 3-1. GDS COMPONENTS

Component	Schematic Number	Purpose	Operating Pressure Range	Temperature Range	Max ΔP (psig)
Check Valves	CV1 - 6	1/4" gas check valves	20.68 x10^{3}kPa	-40°C to 121°C	51.71 x10^{3}kPa
Compressor	CMP1,2	pressure control	10 - 600 kPa	10°C - 40°C	TBD
Storage Tank	STR1,2	pressure control	0-1000 kPa	10°C - 40°C	TBD
Pressure Transducers	PT1-4,6	gas pressure sensors	0-0.344kPa 0-20.68x 10^{3}kPa	0-71°C	TBD
Vacuum Transducers	PT5,7	Vacuum level sensors	10E-3 torr	TBD	TBD
Manual Valve	MV1	gas valve	20.68 x10^{3}kPa	TBD	TBD
Manual Valves	MV2-4	gas pressure valves	1.034x10^3 kPa	-25°C - 150°C	TBD
Solenoid Valves	SV1-5,8,11-16	gas pressure valves	20.68 x10^{3}kPa	25°C - 200°C	TBD
Solenoid Valves	SV6,7,9,10	vacuum line valves	10E-3 torr	25°C - 200°C	TBD
Pressure Relief Valves	PR1-4	Furnace pressure relief	TBD	TBD	TBD
Accumulator	ACC1,2	CMS vacuum chamber	TBD	TBD	TBD
Safety Switches	SS1- 4	QD connected confirmation	TBD	TBD	TBD
Regulators	RE1 & RE2	pressure regulators	20.68 x10^{3}kPa in 137-241kPa out	4 to 49°C	TBD
Quick Disconnect	QD1,2,5,7,9	1/4"gas line QD	TBD	TBD	TBD
Quick Disconnect	QD3,4,6,8	1" vacuum line QD	TBD	TBD	TBD
Filter System	FS1 - FS4	gas supply & Vacuum	20.68 x10^{3}kPa 1.034x10^3 kPa 0-10^{-3}torr	-68 - 71 °C -185 - 71 C TBD	N/A

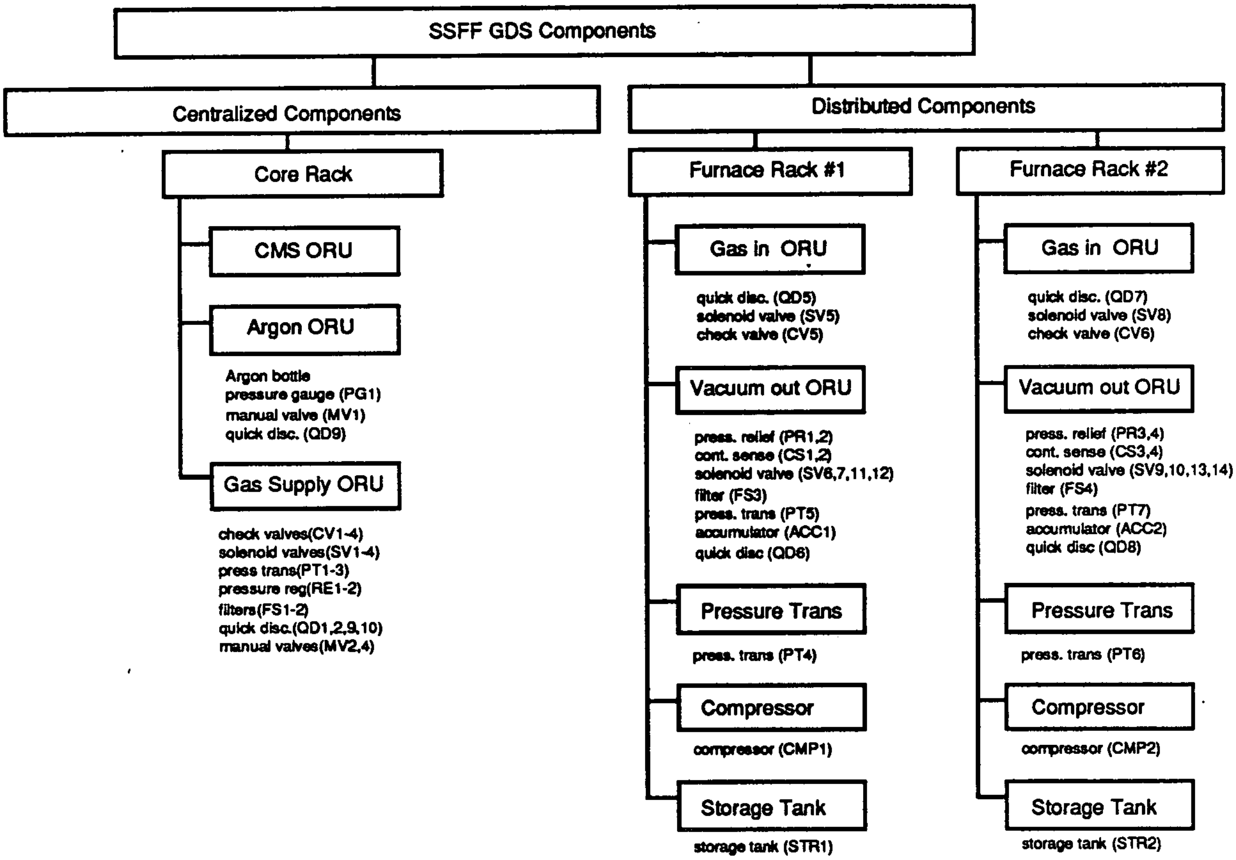
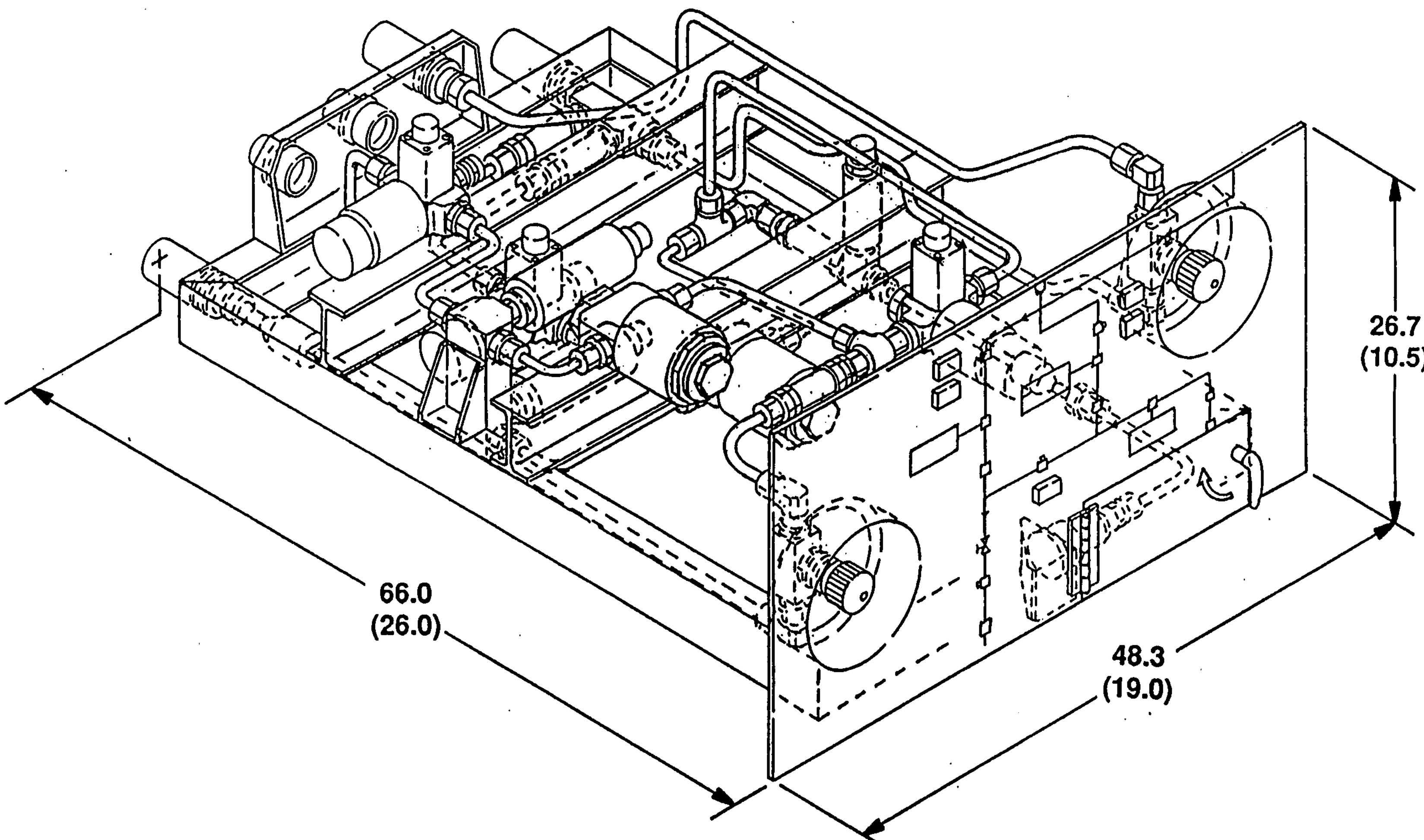


FIGURE 3-5. ORU BREAKDOWN



NOTE: DIMENSIONS IN CENTIMETERS (in.)

Figure 3-6: The Gas Control Assembly is the interface point between the gas supply lines and the furnace modules. It contains an arrangement of check valves, solenoid valves, pressure regulators, and pressure transducers. Components require connections to PCDS and DMS for power and control signals. Line size: 6.35 mm dia. Mass: 10.5 kg.

NOTE: DIMENSIONS IN CENTIMETERS (in.)

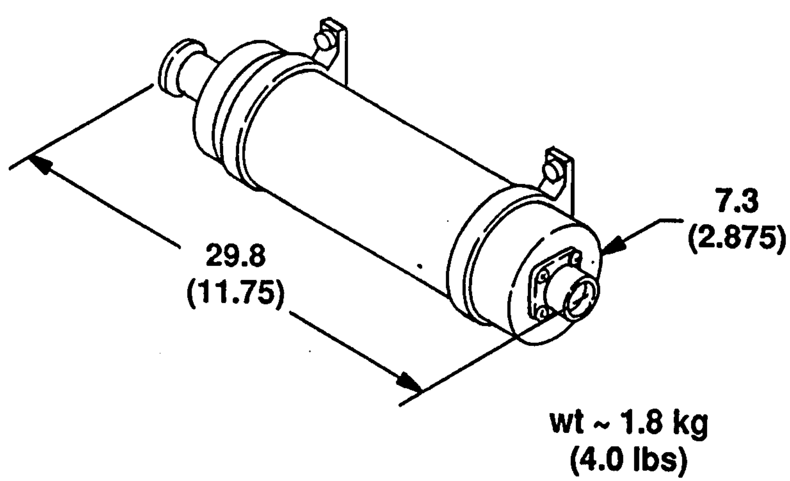


Figure 3-7. The hi-res vacuum sensor is an ORU used to measure the level of vacuum reached in the furnace chamber. Mass: 1.8 kg

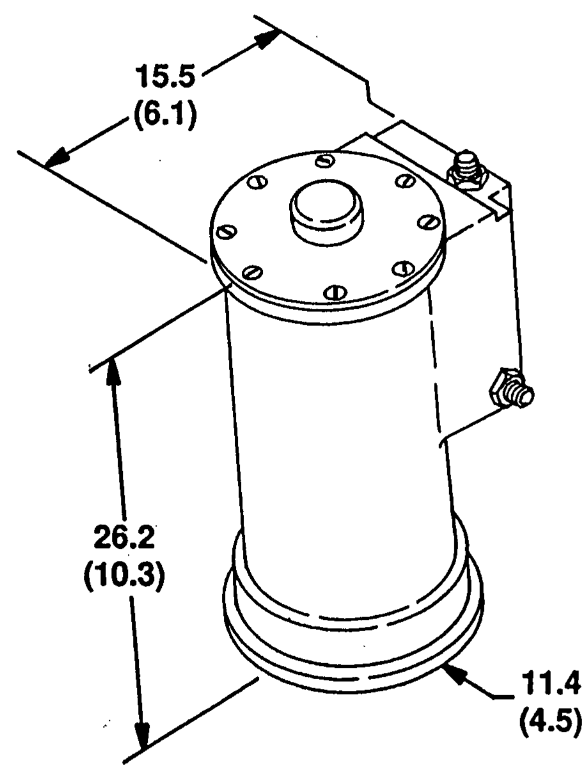
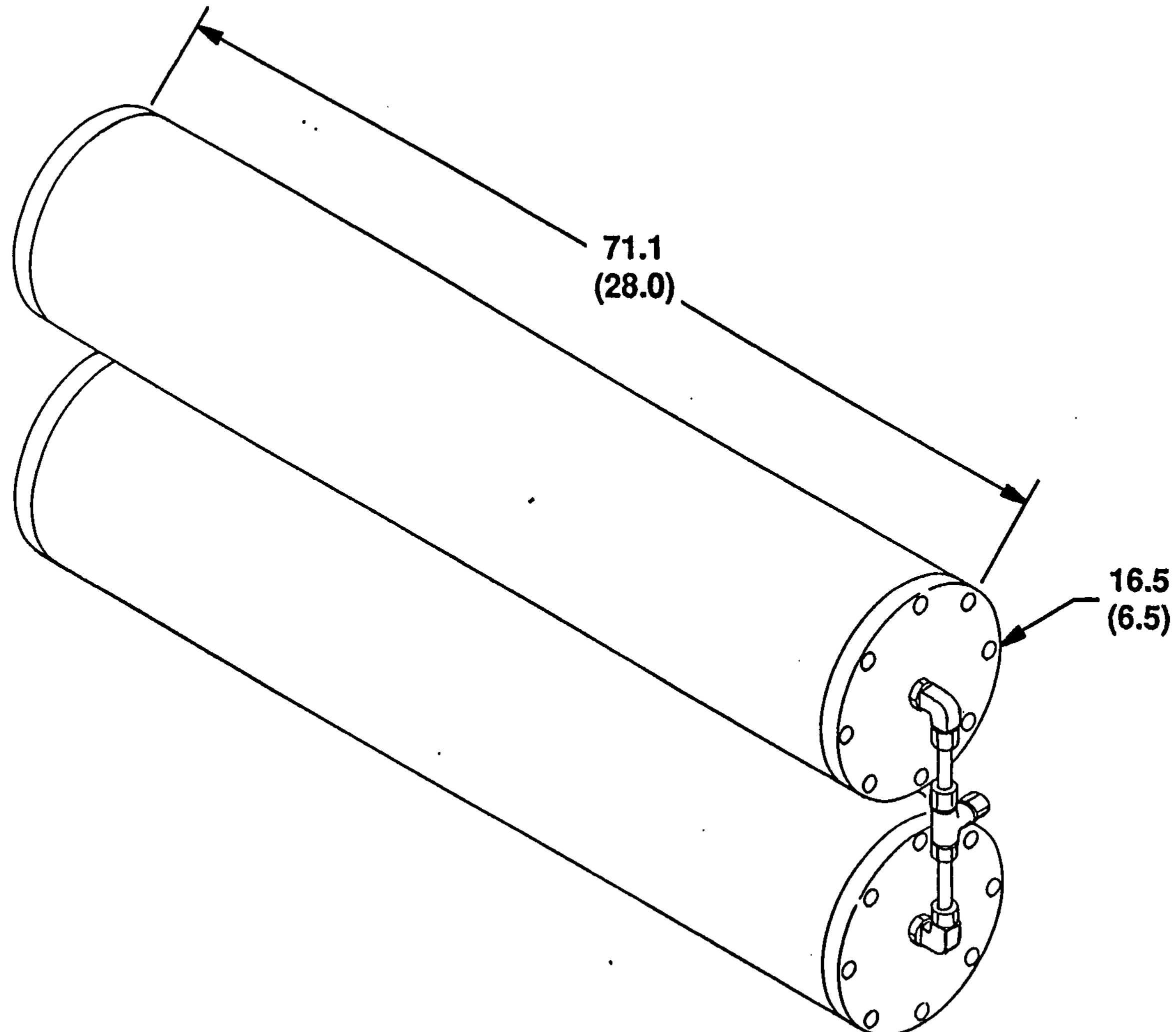
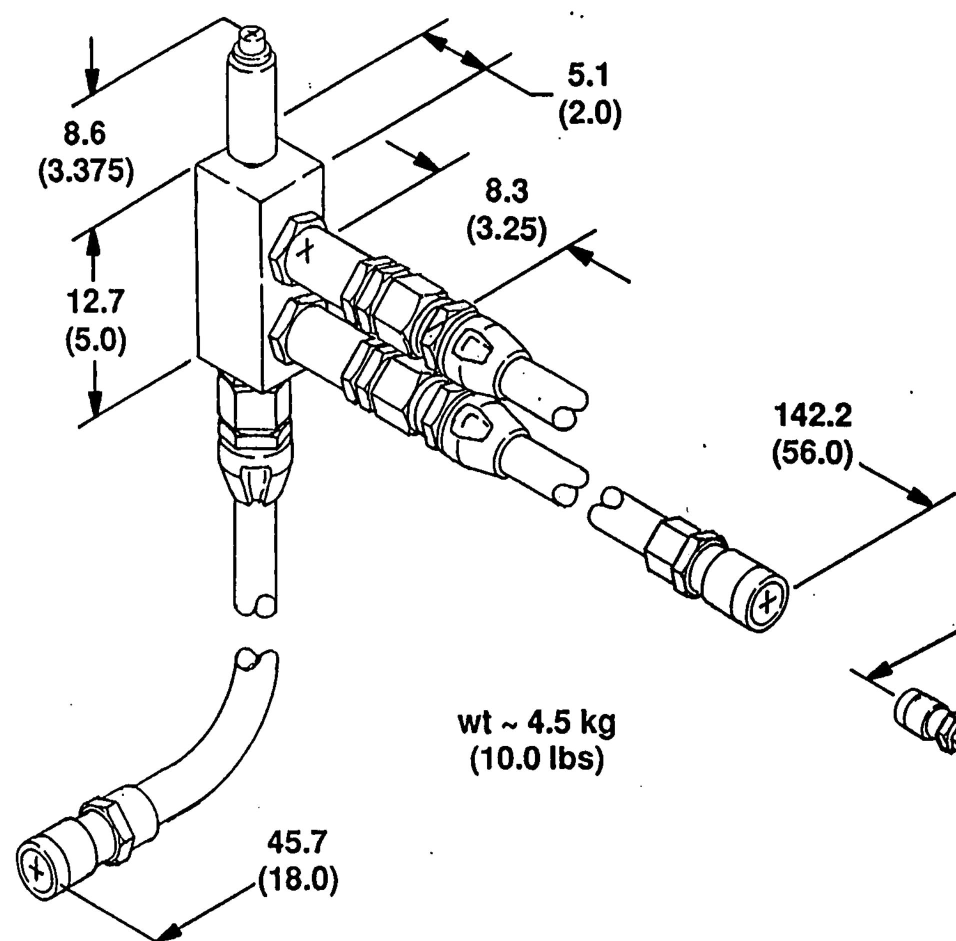


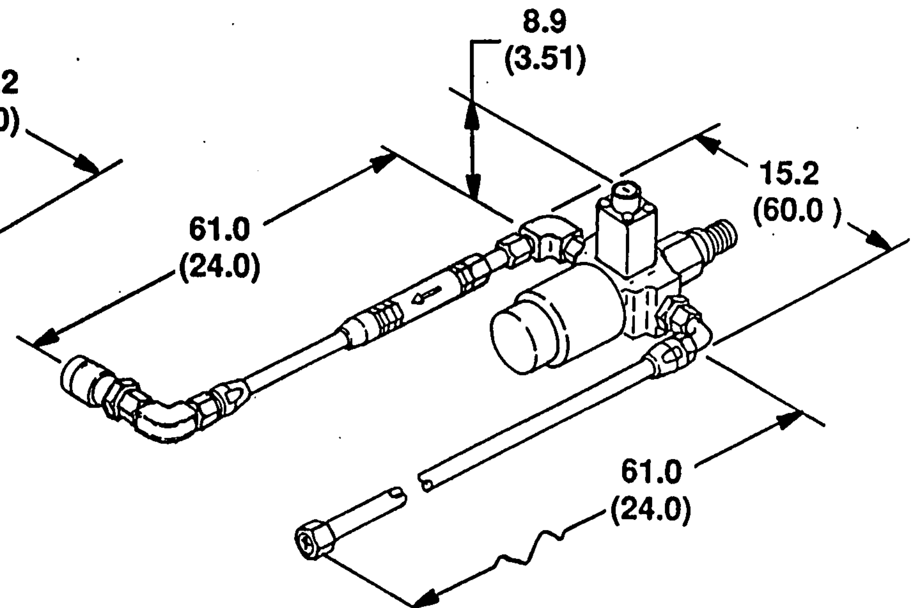
Figure 3-8. The pressure control vacuum pump compensates for small fluctuations in pressure inside the furnace chamber during processing. Mass: 15.0 kg



NOTE: DIMENSIONS IN CENTIMETERS (in.)

Figure 3-9. The storage tanks are used as a temporary holding place for expanding gases as the furnace heats up.
Line size: 6.35 mm dia. Mass: 7.5 kg





NOTE: DIMENSIONS IN CENTIMETERS (In.)

Figure 3-10. The pressure relief manifold connects to the furnace chamber to prevent over pressurization.
Line size: 2.54 cm, Mass: 4.5 kg

Figure 3-11. The gas supply valve assembly connects furnaces to the gas supply.
Line size: 6.35 mm, Mass: 1.8 kg

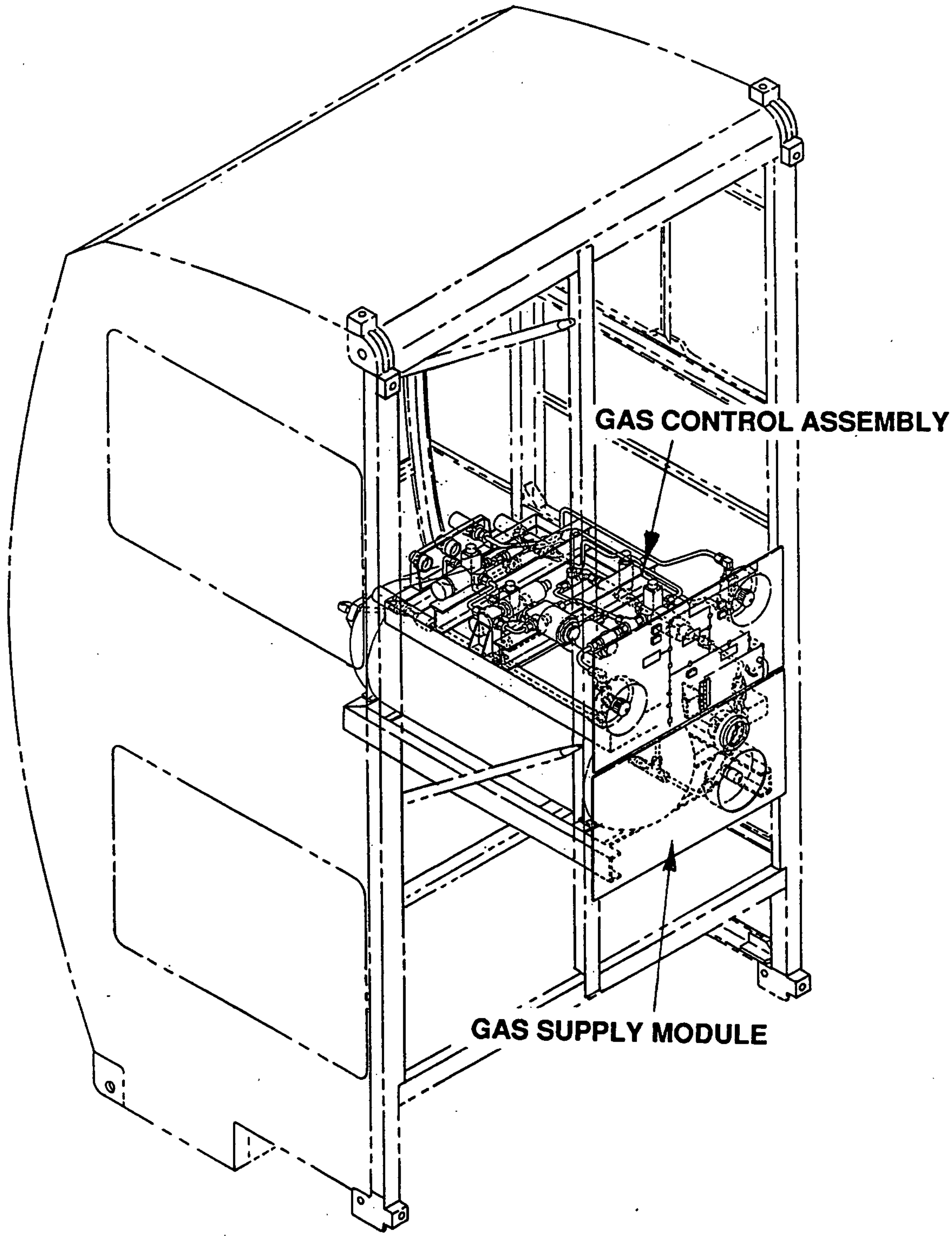


Figure 3-12. Illustration of how centralized GDS components are arranged in the core rack.

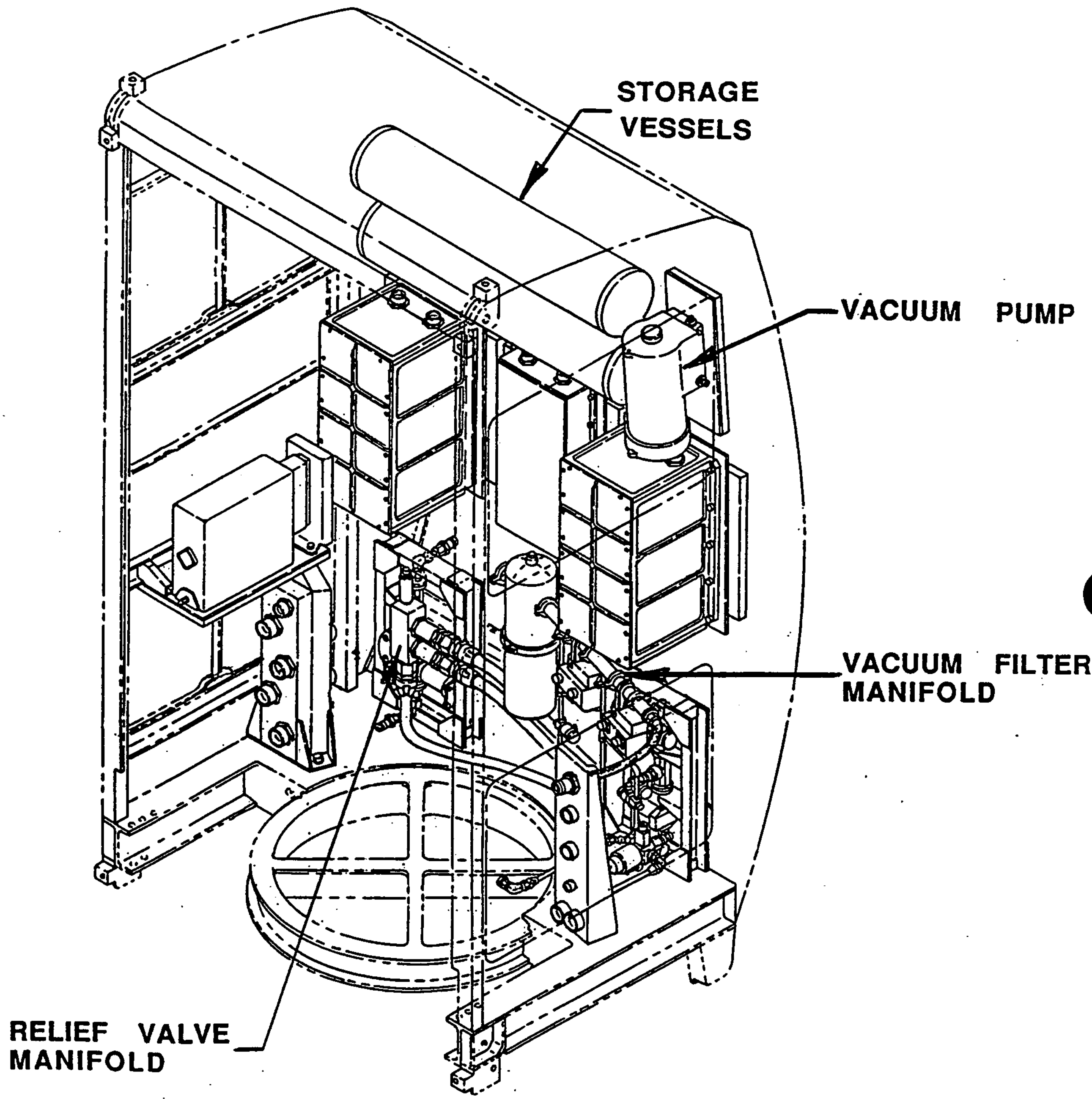


Figure 3-13. Illustration of how distributed GDS components are arranged in the experiment rack.

- Overpressure control of high temperature furnaces processing hazardous experiment sample materials which must be contained to preclude crew exposure to toxic materials and/or release of materials corrosive to SSF hardware. Hazard controls will include provisions for two pressure relief devices on each furnace module (ideally , the issue of "at will" access to the SSF (Vacuum Exhaust System) VES must be resolved to make the use of relief valves a viable hazard control. (Note: the furnace pressure control schemes discussed in para. 3.2.1.2 are for small pressure fluctuations and are not considered as hazard controls).
- The necessity for venting to space through the SSF VES which constrained to accept only "non-hazardous" furnace exhaust products. Obviously, :vent "at will" is not feasible for the furnace modules due to the hazardous nature of many experiment sample materials that are planned to be processed (e.g., mercury). The approach proposed in the present conceptual design (contamination monitoring and filtration of potential furnace exhaust products, combined with the capability to shutdown and seal the furnace if necessary) is acceptable as a hazard control. This assumes that the technology is feasible.
- Use of rotating devices whose structural failure could result is release of fragments. Structural failure of high speed rotating devices such as compressors are typically controlled by containment devices, protective devices such as overspeed control, plus adequate structural design, including application of fracture control techniques.

4. RESOURCE REQUIREMENTS

4.1 POWER

The GDS will require power for several of its components which are listed in the table below. Some of the GDS active components can be manually or remotely operated by the CCU computer to support man-tended or automatic operations. Table 4-1 lists the GDS components requiring power and their operating characteristics. Power estimates for valves, CMS, and compressor are based on a 5% duty cycle.

4.2 MASS AND VOLUME

Table 4-2 summarizes the mass and volume requirement of the components of the GDS.

4.3 SSFF TCS INTERFACE REQUIREMENTS

Most of the GDS components will not require an active cooling system. The only component needing a coldplate will be the Contamination Monitoring System. The level of cooling at max power consumption is estimated at 150 Watts. This is based on using a combination of Non-Dispersive Infrared spectroscopy and X-Ray Fluorescence. If a compressor if used to control the furnace module pressure it will require a TCS coldplate.

4.4 SSFF DMS INTERFACE REQUIREMENTS

The GDS will require several interfaces to the DMS subsystem for control of the following operations: start-up, standard operation, emergency safing, maintenance/ reconfiguration, and shutdown/securing. Under standard conditions the GDS will require minimum crew interaction (manual valves must be configured to enter or leave a secured condition). The DMS system will monitor all valves, sensors, and verification systems within the GDS.

4.6 STRUCTURAL INTERFACE REQUIREMENTS

The GDS components will require adequate mounting structures within the racks for virtually all the components in order to survive the flight and ground handling loads. It is planned to group the majority of the control components into a tray-like assembly approximately the same size as the gas storage module. The face plate of the tray would be the manual operations panel, giving the astronaut access to the manual valves, push button control of the electric valves, and visual indication of the system status.

TABLE 4-1. GDS COMPONENTS REQUIRING POWER

Location	Component	Qty.	Power/each (watts)	Power Req (watts) (5% duty cycle)
Core	Latching Solenoid valve	4	36	7.2
Core	Manual 1" valve	1	2	2
Core	Pressure Transducers	3	1	3
Core	CMS	1	150	7.5
Furnace	Latching Solenoid Valve	12	36	21.6
Furnace	Compressor	2	200	20
Furnace	Pressure Transducer	6	2	12
			Total	**73.3 watts**

TABLE 4-2. MASS AND VOLUME REQUIREMENTS

Location	Component	Dimensions (cm)	Qty.	Mass/Unit (kg)	Total Mass (kg)
Core Rack	Argon Supply & Bottle	26.7 X 45 X 76.2	1	17.5	17.5
	Latching Valve (SV1 - 4)	5.4 X 7.95 X 15.75	4	1.0	4.0
	Manual Valves (MV1,2,4)	4.29 X 2.54 X16.5	3	0.22	0.66
	1" Manual Valve (MV3)	8.2 X 6.4 X 18.5	1	2.35	2.35
	Regulator (RE1,2)	11.7 X 5.4 dia	2	0.9	1.8
	1/4" Filter (FS1,2)	11.89 X 2.84 dia.	2	0.17	0.34
	Pressure Trans (PT1,2,3)	12.4 X 5.94dia	3	0.175	0.51
	Pressure Gauge (PG1)	11.43 dia	1	0.5	0.5
	Contamination Monitor	TBD	1	30.0	30.0
	Check Valves (CV1 -4)	5.0 X 1.68 dia.	5	0.16	0.80
	1/4" Q Disconnect(QD1,2,9)	TBD	3	0.11	0.33
	Vacuum QD (QD3,4)	TBD	2	1.60	3.20
	Plumbing/Hoses/Fittings	TBD	N/A	6.00	6.00
Furnace Rack	Latching Valve(SV5,16)	5.4 X 7.95 X 15.75	12	1.00	12.00
	Pressure Relief (PR1 - 4)	14.1 X 5.1dia	4	1.6	6.4
	Vacuum Filter(FS3,4)	11.89 X 5.0 dia	2	3.63	7.26
	Pressure Transducer(4-9)	12.4 X 5.94dia	6	0.17	1.02
	Compressor (CMP1,2)	26.2 X 11.5 X15.5	2	15.00	30.00
	Waste Gas Storage (STR1,2)	26.7 X 45 X 76.2	2	17.5	35.00
	Q Disconnect(QD5,7)	TBD	2	0.11	0.22
	Vacuum QD (QD6,8)	TBD	2	1.60	3.20
	Accumulator (ACC1,2)	TBD	2	0.50	1.00
	1/4" Check Valves (CV5-8)	5.0 X 1.68 dia.	4	0.16	0.64
	Plumbing/Hose/Fitting	TBD	N/A	2.0	2.0
				Total	**162.85 kg**

TABLE 4-3. GDS DMS REQUIREMENTS

Component Name	Schematic number	Qty.	Signal Type	Signal Purpose	Sample Rate (samples/sec)	Bit Conversion
Pressure Sensor	PT1-PT8	8	1 analog output per sensor .	sense pressure	1	16
Manual Valve	MV3	1	2 analog	pos. indication	1	16
Solenoid Valves	SV5 - SV8	2	1 relay control +2 analog	close/ open, indication	1	16
Switches	SS1-SS4	4	analog .	QD connected	1	16

5. ISSUES AND CONCERNS

The main concerns of this concept are problems dealing with trying to vent gases with contaminant levels to the SSF and the active control of the pressure inside the furnace module. To deal with this issue, gas analyses of furnaces operating under normal (no ampoule breakage or leaking) conditions will be submitted to SSF for approval as acceptable vent products to the vacuum exhaust system. Therefore the furnaces operating normally should be able to vent directly to the SSF. If the gas analysis indicates abnormal contaminant levels (possible ampoule leak or break) the furnace will be shut down and sealed (to prevent spreading contamination) for the remainder of the mission. The waste gases will be monitored by a Contamination Monitoring System.

Active control of pressure is another concern of this report. Due to the restrictions on contaminant levels and scheduling of access to a vent line limits the amount of control of pressure achievable without impacting the design of the furnace modules. Eliminating the requirement for active control of pressure for furnace modules would relieve design difficulties and leave more room for furnace modules in the experiment racks.

APPENDIX A

CALCULATIONS

APPENDIX A: CALCULATIONS

<u>Gas Storage Calculations:</u>

Gas Equations: $m = pV/RT$

Argon: R = 38.7

Bottle Storage Volume:

$m = (3{,}014.7\text{psi})(144)(.94\text{ cu.ft})/(38.7\text{ ft-lbf/lbm-R})(537\text{R})$

$= 19.6$ lb/bottle

2 Furnaces with 4 Argon fills/90 days:

$m=(12\text{ psi})(144)(200\text{ cu.ft})/(38.7\text{ ft-lbf/lbm-R})(537\text{R})$

$=16.63$ lbm

Therefore, approximately 85% of the supply bottle will be required. The bottle module would have to be replaced before starting a new batch of samples on the next mission.

<u>Nitrogen required from SSF for furnace purges:</u> R=55.2

2 Furnaces with 8 vents/90 days:

$m = (12\text{psi})(144)(400\text{ cu.ft})/(55.2\text{ ft-lbf/lbm-R})(537\text{R})$

$= 23.3$ lbm

Therefore, approximately 23 lbs of nitrogen is required from SSF.

<u>Waste Gas Bottle Storage Needed</u>

If both the argon and nitrogen had to be pumped to the waste gas storage bottle, it would take 3 bottles to store the volume of gas just calculated at 3000 psi, see below.

For 2 Furnaces, 2 Sample Runs Each, 90 days:

23.3 lbm nitrogen + 16.63 lbm argon = 39.93 lbm total

Per Sample = 4 nitrogen purges + 2 Argon Purges = 19.96 lbm

The molecular weight of nitrogen is greater than argon therefore a 3000 psi waste gas bottle can hold:

$m = (3014.7)(144)(.94)/(55.2)(537) = 13.77$ lbm nitrogen.

Following the operational sequence outlined we would see the following:

1st Bottle,	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
1st Sample:	2 Argon purges	= 8.32 lbm	(42.4% of bottle)
	Total	= 14.15 lbm	(84.7% Full) Change Bottle
2nd Bottle,	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
1st Sample:			
Load 2nd Sample			
	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
	Total	= 11.66 lbm	(84.6% Full)
Change Bottle			
3rd Bottle,	2 argon purges	= 8.32 lbm	(42.4% of bottle)
2nd Sample:	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
	Total	= 14.15 lbm	(84.7% Full)

Therefore it will take three waste gas storage bottles and one argon supply bottle for the 2 furnace, 2 sample, 90 day scenario described.

Storage Option

The technical feasibility of compressor hardware to achieve 3000 psi storage pressures while producing a vacuum suction, has not been established. The most likely candidates can only produce something like a 90 psi discharge head. On that basis the waste gas storage volume will be recalculated, this time assuming that only the argon process gas is stored and that the nitrogen purge gases are vented.

200 cu ft @ 12 psia = x cu ft @ 90 psia
x = 26.7 cu ft @ 90 psia

This corresponds to roughly half the available volume of a standard space station rack.

Pressure control calculations:

Assumptions: Absolute max pressure able to compress to 100 psi. Pressure rise in furnace no greater than 2 psi. Volume of furnace chamber 25 ft^3. Operating pressure: 10 psi. Volume of control storage tanks.

Initial mass of argon in furnace chamber:

$PV = mRT$ Argon: $R = 38.7$ (ft-lbf/°R-lbm) Volume = 25 ft^3

$T = 25$ °C (77°F) $P = 10$ psi

$$m = \frac{PV}{RT} = \frac{(10\ lb/in^2)(144\ in^2/ft^2)(25\ ft^3)}{(38.7\ ft\text{-}lbf/°R\text{-}lbm)(537\ °R)} = 1.732\ lbm$$

Temperature of gas after 2 psi pressure increase:

$$T_2 = \frac{PV}{mR} = \frac{(12\ lb/in^2)(144\ in^2/ft^2)(25\ ft^3)}{(1.73\ lb)(38.7\ ft\text{-}lbf/°R\text{-}lbm)} = 645\ °R\ (185\ °F)$$

Mass of argon in furnace at T_2 maintaining pressure of 10 psi:

$$m_2 = \frac{PV}{RT} = \frac{(10\ lb/in^2)(144\ in^2/ft^2)(25\ ft^3)}{(38.7\ ft\text{-}lbf/°R\text{-}lbm)(645\ °R)} = 1.4422\ lbm$$

Amount of mass to be stored to maintain constant pressure in furnace chamber

$$m - m_2 = 1.732\ lbm - 1.4422\ lbm = 0.2898\ lbm$$

Amount of argon that can be stored in pressure control vessels:

$$m = \frac{PV}{RT} = \frac{(100\ lb/in^2)(144\ in^2/ft^2)(.94\ ft^3)}{(38.7\ ft\text{-}lbf/°R\text{-}lbm)(537\ °R)} = 0.65\ lbm$$

Number of samples that can be processed before storage tank is full :

$$\#\ of\ samples = \frac{0.65\ lb\ total\ storage}{0.29\ lb/sample} = 2.24\ samples$$

APPENDIX B

TRADES AND ANLYSIS

APPENDIX B: TRADES AND ANALYSIS

Trades and Analysis: Due to the various options for handling the waste gas problem on SSFF it would be beneficial to perform studies in the following areas:

1. Gas analysis techniques to determine the most desirable method for indicating contamination levels of the gases of SSFF.
2. Filtering and particulate removal in gases.
3. Waste gas handling techniques.

APPENDIX C

COMPONENT SPECIFICATIONS

Component Specification Sheet
SSFF GDS-ARG

Component ID #: GDS-ARG

Nomenclature: Gas Supply Module

Description: This module supplies processing gas to the furnace modules. Initially it will hold 8.8 kg of Argon at 20,684 kPa. The module will use quick disconnects for connecting to and from the Gas Control Assembly. Line size is 6.35 mm dia.

Quantity: 1

Input Voltage: N/A

Heat Rejection: N/A

Dimensions: 26.7 x 48.3 x 83.8 cm (10.5" x 19" x 33") HWD

Mass: 22.5 kg (full)

Component Specification Sheet
SSFF GDS-VO

Component ID #: GDS-VS

Nomenclature: Vacuum Supply Assembly

Description: The Vacuum Supply Assembly is a collection of tubing, valves, pressure transducers, filters, and contamination sensors. Waste gases from the furnaces are routed through this unit which filters and holds a sample of the process gas while contamination analysis is being performed. The diameter of the vacuum line is 1".

Quantity: 2 (GDS-VS-1 & GDS-VS-2)

Input Voltage: 120 Vdc for operation of the valves

Heat Rejection: TBD

Dimensions: TBD

Mass: TBD

Component Specification Sheet
SSFF GDS-STR

Component ID #: GDS-STR-1

Nomenclature: Gas Pressure Control Storage Vessels

Description: The storage vessels are used as a temporary holding place for expanding gases as the pressure inside the furnace chamber rises. Two vessels (16.5 dia x 71.1 cm long) will be ganged together. A compressor will be used to pump gases into the storage vessels. The line to the tank will be 1/4" dia.

Quantity: 2 (GDS-STR-1 & GDS-STR-2)

Input Voltage: N/A

Heat Rejection: N/A

Dimensions: 33 x 16.5 x 71.1 cm (two vessel attached together)

Mass: 15 kg

Component Specification Sheet
SSFF GDS-CMP

Component ID #: GDS-CMP-1

Nomenclature: Pressure Control Vacuum Pump

Description: The vacuum pump is used to control the pressure inside the furnace inside the furnace module during heat up. The compressor stores excess gases in the storage vessels to maintain constant pressure inside the furnace as the gas expands. A cooling jacket is built in to the compressor.

Quantity: 2 (GDS-CMP-1 & GDS-CMP-2)

Input Voltage: 120 Vdc

Heat Rejection: TBD watts into a cooling jacket.

Pressure Diff: 90 psid

Dimensions: 26.2 cm x 11.4 cm x 15.5 cm

Mass: 15 kg

Component Specification Sheet
SSFF GDS-GI

Component ID #: GDS-GI

Nomenclature: Gas Supply Valve Assembly

Description: The GDS-GI is the interface point to the furnace module for gas distribution. It consists of a quick disconnect, solenoid valve and check valve. The valve is controlled through a connection to DMS which regulates the flow of gases into the furnace chamber. Line size for gas supply is 1/4" dia.

Quantity: 2 (GDS-GI-1 &GDS-GI-2)

Input Voltage: 120 Vdc for operation of the valve

Heat Rejection: N/A

Mass: 1.8 kg

Component Specification Sheet
SSFF GDS-PRS

Component ID #: GDS-PRS-1

Nomenclature: Hi-Res Vacuum Sensor

Description: The vacuum sensor indicates the level of vacuum within the furnace chamber.

Quantity: 2 (GDS-PRS-1 & GDS-PRS-2)

Input Voltage: 120 Vdc

Dimensions: 29.8 cm x 7.3 cm dia

Mass: 1.8 kg

Component Specification Sheet
SSFF GDS-CMS

Component ID #: GDS-CMS-1

Nomenclature: Contamination Monitoring System

Description: This unit processes the data from the contamination sensors located in the furnace racks to determine levels of contamination of the furnace process gases before they can be vented to the SSF VES.

Qty. 1

Input Voltage: 120 Vdc

Heat Rejection: 150 W

Dimensions: 40.64 cm x 40.64 cm x 26.67 cm (Possible Envelope dimensions)

Mass: 30 kg

SPACE STATION FURNACE FACILITY THERMAL CONTROL SUBSYSTEM (SSFF TCS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

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320RPT0008

SPACE STATION FURNACE FACILITY THERMAL CONTROL SUBSYSTEM (SSFF TCS) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
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EXECUTIVE SUMMARY

This report is part of a research study entitled "Space Station Furnace Facility" and the analyses and investigations presented are intended to fulfill the requirements set forth in the Science Capability Requirements Document (SCRD) as it pertains to the Thermal Control Subsystem (TCS). This concept is an update from that presented at the SSFF 6th Quarterly review held January 22, 1992. The work was done by the Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration.

Contents of this study include a description of the requirements, ground rules and assumptions, concept design, description of individual components, resource requirements, issues and concerns, and analyses to back up the current design.

The documented requirements were evaluated and ground rules and assumptions derived from those requirements. Analyses were then performed on the Space Station Furnace Facility (SSFF) TCS and it was determined that cooling for SSFF components should be isolated from the Space Station Freedom (SSF) TCS to the largest extent possible instead of direct cooling of coldplated electronics by the SSF TCS, due to the number of custom-built coldplates required in the system. This implies a secondary SSFF closed cooling loop which cools the core electronics and furnace modules with the only interface to the SSF TCS being through a rack heat exchanger.

The SSFF TCS water cooling loop collects heat from the furnace modules and subsystem electronics. The collected heat is then transferred to the Space Station Thermal Control System via the core rack heat exchanger. During operation, coolant is directed in a single cooling line from the Coolant Pump Assembly outlet through the heat exchanger, then branches into a three-branch parallel system, each rack containing one cooling line. Each rack line branches into two parallel legs to flow through the coldplate mounted equipment, so that the TCS contains a total of six parallel legs, two in each rack. The cooling lines in the experiment racks rejoin into one line before the furnace modules so that the entire flow is available for cooling of the module. The three separate rack cooling lines rejoin into one line in the core rack, then the entire flow enters the Coolant Pump Assembly inlet.

The total current mass of the SSFF TCS is 191 kg, total volume is 193900 cm^3, total power required is 201 W, and heat rejection is 148 W which will be cooled partially by Avionics Air, and partially by cooling water.

Issues and concerns for the TCS include the following:

1. <u>SSF-Allocated Flowrate</u>

   The SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet

temperature. For low SSFF heat loads, the SSF cooling water flow to the SSFF core rack will not be sufficient to maintain the 50°C coldplate surface temperature to all coldplates in the core rack. This concern is documented and explained in more detail in the memorandum, "Space Station Freedom (SSF) Thermal Control System (TCS) Allocations", APD91-023.

2. Payload Heat Exchanger Limitation

The current maximum capacity of the SSFF TCS is 8 kW, since the heat exchanger approved for payload use to interface with the SSF TCS is limited to 8 kW. Since the core rack will reside in a 12 kW rack location, the possibility exists that up to 12 kW will need to be dissipated at one time, indicating the need for another heat exchanger and possibly a Coolant Pump Assembly. The impacts to SSFF would be an increase in volume and mass due to more TCS components in the rack. At this time, analysis shows that one heat exchanger is adequate, since the heat load is currently less than 8 kW.

ABBREVIATION AND ACRONYMS

abs	absolute
cc	cubic centimeter
CCU	Core Control Unit
CGF	Crystal Growth Facility
CM	Contamination Monitor
cm	centimeter
CMCU	Core Monitor and Control Unit
CMS	Contamination Monitor System
CPCS	Core Power Conditioner Stimulus
DCMU	Distributed Core Monitor Unit
DMS	Data Management Subsystem
ESA	European Space Agency
FAU	Furnace Actuator Unit
FCU	Furnace Control Unit
GDS	Gaseous Distribution Subsystem
GSE	Ground Support Equipment
hr	hour
Hz	Hertz
in	inch
IRD	Interface Requirements Document
ISPR	International Standard Payload Rack
kg	kilogram
kPa	kiloPascal
kW	kilowatt
lb	pound
max.	maximum
MDP	Maximum Design Pressure
MTC	Man Tended Capability
mv	millivolt
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency
ORU	Orbital Replacement Unit
PCDS	Power Conditioning and Distribution Subsystem
Pkg	Package
psi	pounds per square inch
Qty	Quantity
RFCA	Remote Flow Control Assembly
RPCM	Remote Power Controller Module
RTD	Resistance Temperature Device
SCRD	Science Capability Requirements Document
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To be determined
TCS	Thermal Control Subsystem
V	volts
VAC	volts (alternating current)
VDC	volts (direct current)
W	watts
WP-01	Work Package-01
°C	degrees Celsius
°F	degrees Fahrenheit

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The scope and purpose of this report is to present the Space Station Furnace Facility (SSFF) Thermal Control Subsystem (TCS) requirements and design concept developed that meet those requirements, and to summarize the continuing study and analyses on the SSFF TCS conceptual design. The report includes a description of the requirements, an overall TCS concept, and descriptions of the individual components.

The SSFF consists of a core rack which will provide a set of standard support services to one or more experiment racks. At this time, the facility is configured to operate with two separate experiment racks. The variety of furnaces which could operate with the SSFF core will demand adaptability in the core configuration to provide the different resources needed to properly operate each furnace type. In the TCS, this adaptability is provided by allowing for a cooling flow to each experiment rack which can be varied to accommodate different heat loads for different furnaces.

The SSFF TCS will provide the thermal heat sink for the furnace modules included in the facility as well as heat loads of the coldplate-mounted or cooling-jacketed electronics in the core rack and experiment racks. This subsystem is comprised of a closed water loop which performs the following functions:

- Collection of heat dissipated by the furnace modules.
- Collection of heat dissipated by the SSFF subsystems in the core rack and experiment racks.
- Heat transport.
- Rejection of heat to the Space Station Freedom (SSF) Laboratory Customer Thermal Control System.

Space Station Freedom will provide the cold side cooling water supply for the rack heat exchanger. Access to the SSF water supply will be through the Rack Flow Control Assembly.

Limited Avionics Air will also be available to cool valves and sensors.

1.2 GROUNDRULES AND ASSUMPTIONS

1. Approximately 90% of the total heat load in the SSFF will be water cooled due to limited Avionics Air resources.
2. Heat load profiles are not the same as the power profiles reported for the electrical design in all cases. The reason for this is that there is always a lag both in time and maximum amplitude between the instantaneous power and the heat rejected due to the transient temperature response of the furnace and other items of hardware. Estimates have been made for the furnaces based on Crystal Growth Facility (CGF) test data. For Data

Management Subsystem (DMS), and some other hardware, worst case is assumed (power in is equal to heat rejected) where heat loads are not known.

3. 50°C is considered to be the highest temperature which is feasible for electronic boxes to have as a heat sink, since 125°C is assumed to be the maximum allowable operating temperature for the components.

4. The U. S. Lab module moderate temperature cooling loop will serve as the SSFF interface with SSF TCS. The moderate temperature loop is assumed to be available for SSFF operation at Man Tended Capability (MTC) and throughout SSF operation.

5. The inlet temperature of the SSF TCS cooling water supply to the heat exchanger is assumed to be 18.3 °C (NASA only, ref Contract Change No. PCP-BP-00400).

6. Heat exchanger temperature designations are as follows:

   Space Station provided:
   - SSF TCS cooling water supply is designated cold side inlet temperature
   - SSF TCS cooling water return is designated cold side outlet temperature

   SSFF water cooling loop:
   - SSFF TCS cooling water supply is designated hot side outlet temperature
   - SSFF TCS cooling water return is designated hot side inlet temperature

7. SSFF TCS will use the standard WP-01 coldplates, heat exchanger, valves, and sensors where feasible. Performance characteristics for these standard items are assumed from available data (see Appendix B, Component Data Sheets).

8. Avionics Air is assumed to be available in each of the SSFF racks, and will be used for cooling of SSFF sensors and valves, with the exception of the SSFF TCS, where half the heat from the valves and sensors is assumed to be rejected to the cooling water.

2. REQUIREMENTS

2.1 GENERAL

The requirements for the SSFF TCS are found in 320SPC0001, Function and Performance Specification for Space Station Furnace Facility.

2.2 INTERFACE REQUIREMENTS

2.2.1 SSF TCS Interface

Figure 2.2.1-1 shows the SSF to SSFF interface block diagram. The SSF U. S. Lab Module moderate temperature cooling supply shall be utilized by the SSFF TCS. Table 2.2.1-1 shows the characteristics of the moderate temperature loop at the interface to the user rack. Interface with the SSF TCS is via the Rack Flow Control Assembly (RFCA) located in the standoff below the SSFF Core Rack through the ISPR Interface Panel. The 18.3°C (65°F) water supply provided by SSF will be used to interface with the SSFF TCS water cooling loop via the rack heat exchanger. Per the Payload Accommodations Handbook, SS-HDBK-0001, "The RFCA can maintain either a specific flow rate or a specific outlet temperature as determined by the user. Both modes of control will be available for any particular application, but only one mode may be active at any one time at a specific location.". Realistically, the SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet temperature, but if the user's experiment temperature is out of limits, he may request a higher flow rate than that which is allocated to him. Table A-1 of Appendix A contains the spreadsheet which calculates line and coldplate temperatures for the specified SSFF heat load of 7087 watts, which corresponds to an SSF allocated flowrate of 192.5 kg/hr. The temperature locations on the spreadsheet correspond to the circled numbers on the schematic in Figure A-1. To maintain the design coldplate surface temperature of 50 °C, the allocated SSF TCS flow rate is currently not adequate, and calculations were performed to determine what coldside flow rate would allow the SSFF coldplate temperatures to be at or below the 50 °C. Table A-2 of Appendix A contains these calculations, which shows that a coldside flow rate of 238 kg/hr is required to meet the SSFF design limits.

A limited amount of SSF Avionics Air cooling is available for dissipating heat not rejected to the water cooling loop. Part of the heat dissipated by electric sensors and electromechanical valves shall be dissipated by the flow in the TCS and the rest shall be dissipated by Avionics Air. Avionics Air will collect the heat rejected by lines and connectors, and other items such as the crew interface. The total maximum and nominal thermal requirements of the SSFF TCS avionics air allocation are given in Table 2.2.1-2.

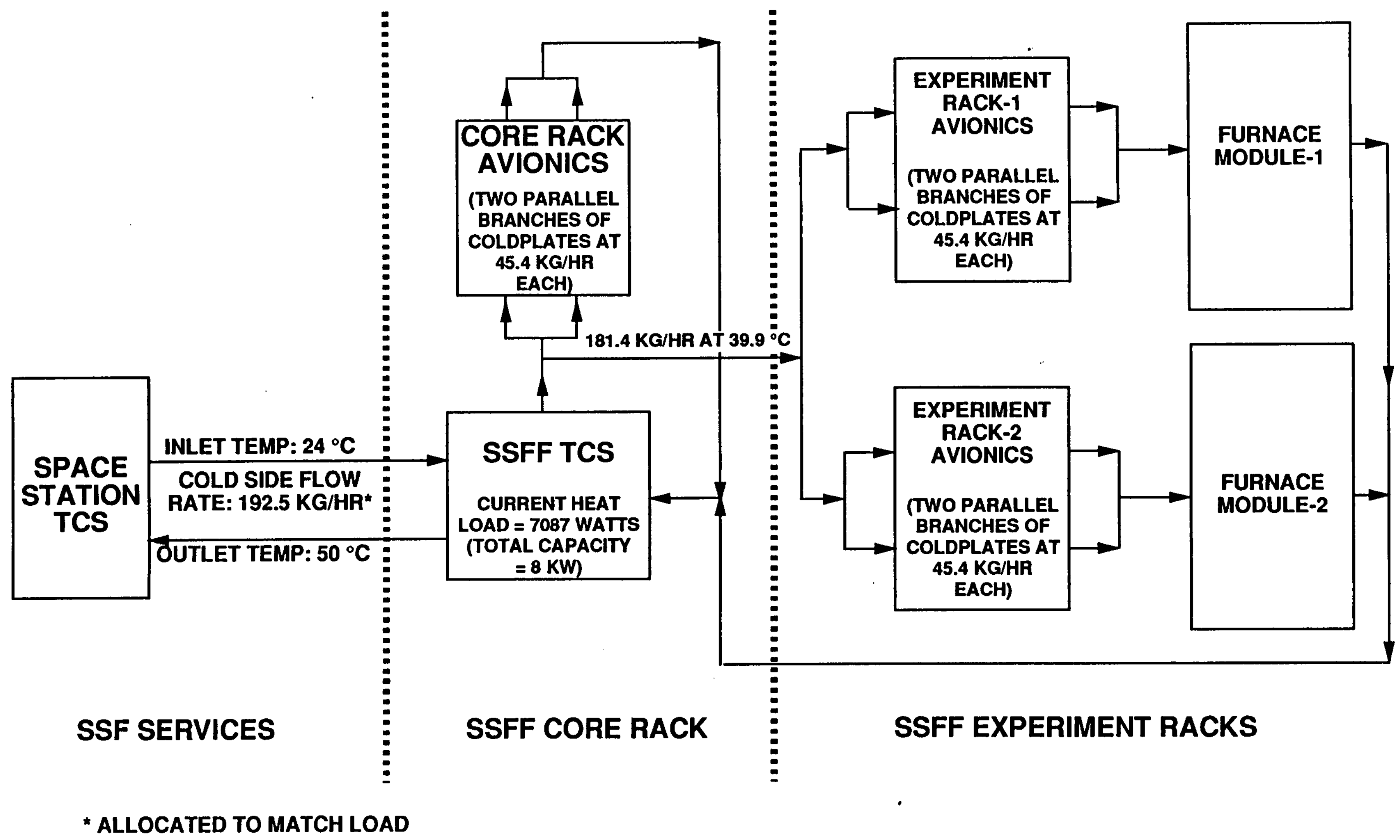


FIGURE 2.2.1-1. SSF TO SSFF INTERFACE BLOCK DIAGRAM

TABLE 2.2.1-1. SSF THERMAL CONTROL SUBSYSTEM INTERFACE CHARACTERISTICS*

Supply Temperature (non-selectable range):	16° - 18.3°C (61° - 65° F) (NASA only)
Maximum Return Temperature:	50°C (122 °F)
Heat Removal Capability:	12 kW (NASA only)
Pressure Differential at Design Flow Rate Across Inlet/Outlet:	40 kPa (5.8 psi)
Maximum Operating Pressure	834.3 kPa (121 psi)
Maximum Rack Flow Rate	326.5 kg/hr (719 lb/hr) (NASA 12 kW rack only)

* Data taken from International Standard Payload Rack to NASA/ESA/NASDA Modules Interface Control Document, Draft 12, (SSP 41002), November 19, 1991, NASA, Huntsville, Alabama, and Contract Change No. PCP-BP-00400.

TABLE 2.2.1-2. SSF AVIONICS AIR SYSTEM PERFORMANCE PARAMETERS *

Inlet Air Temperature (non-selectable)	17 - 22°C (63 - 72°F)
Outlet Air Temperature	43 °C (109°F) maximum
Dew Point (inlet and outlet)	≤15.5°C (60°F)
Heat Removal Capability	1.2 kW
Pressure Differential Across Inlet/Outlet at Design Flow Rate	0.5 kPa (0.07 psi)
Cooling Standard	At least 175 kg/hr/kW (385 lb/hr/kW)

* Data taken from International Standard Payload Rack to NASA/ESA/NASDA Modules Interface Control Document, Draft 12, (SSP 41002), November 19, 1991, NASA, Huntsville, Alabama.

2.2.2 SSFF TCS Furnace Module Interface

The SSFF TCS water cooling loop interfaces with the furnace module cooling jackets by quick disconnects, and removes heat generated by the furnace modules. During operation, coolant is directed from the coolant pump assembly outlet through the heat exchanger in the core rack. This water then flows through a three-branch parallel system (one branch in each rack). When the cooling line enters the experiment rack, it separates into two separate lines and flows through two parallel legs of coldplates and cooling-jacketed items, then rejoins and flows through the furnace module. The TCS removes the heat generated by the furnaces, and those SSFF components mounted to coldplates and cooling jackets, then flows back to the coolant pump assembly inlet.

2.2.3 SSFF TCS Subsystem Interface

The SSFF TCS interfaces with the SSFF centralized and distributed subsystem equipment by providing coldplates for water cooling and interfaces with cooling-jacketed equipment. The core rack cooling line separates into two parallel lines for cooling of the ten core rack coldplates, four coldplates in one parallel leg, and six in the other, then rejoins after the coldplates and flows back to the coolant pump assembly inlet, rejoining the furnace cooling line at the inlet. Cooling of the experiment rack subsystem equipment is described in Section 2.2.2.

2.2.4 Crew Interface

Crew interface includes opening and closing of manual valves, and changeout of ORUs. No routine crew interface with TCS is required during normal SSFF operations.

2.2.5 GSE Interface

Initial charging of the coolant pump assembly accumulator and filling of the cooling lines with water is required prior to flight.

3. CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

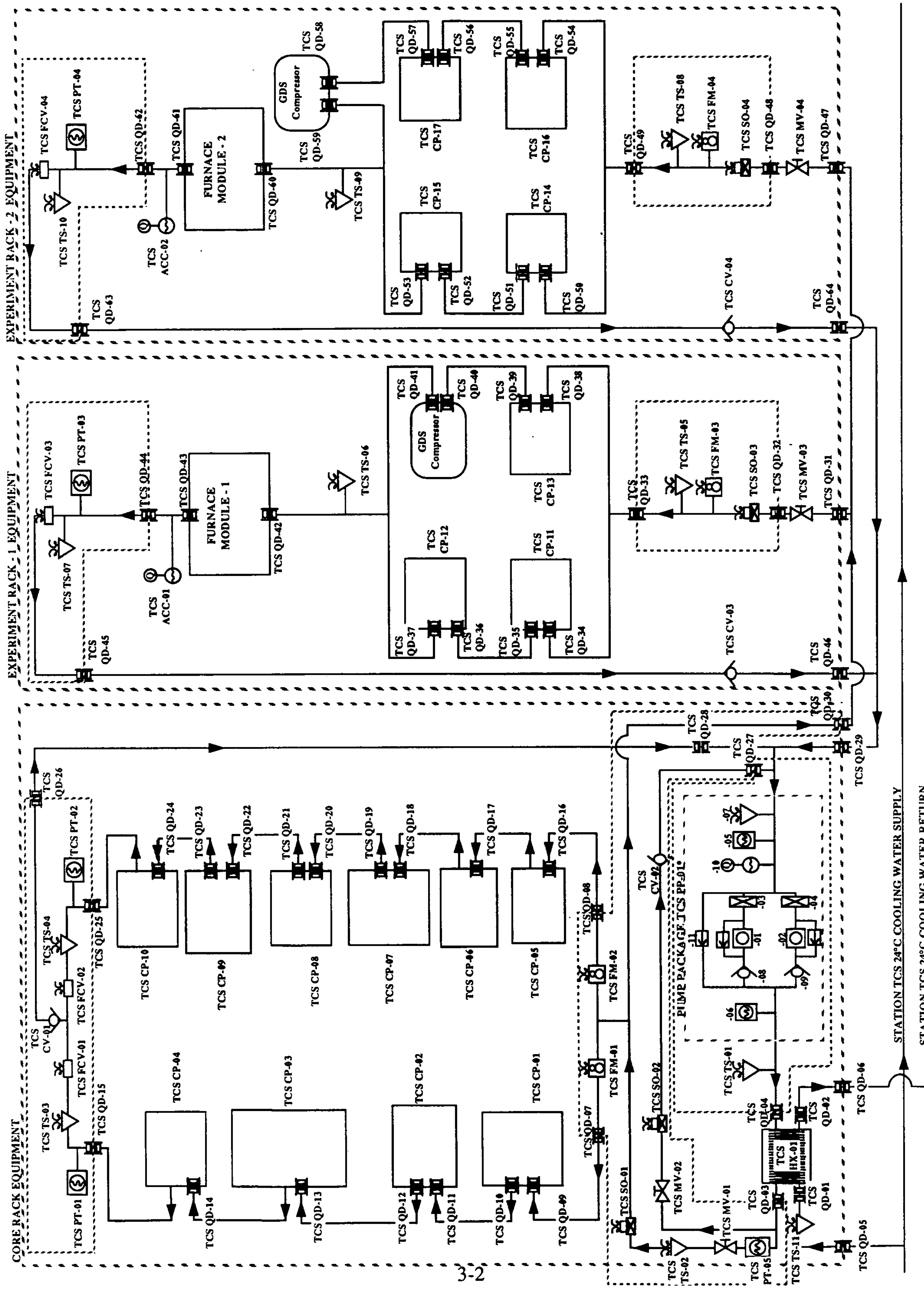
In addition to the current configuration, a concept in which two separate cooling loops are utilized was studied. In this concept, the core coldplates are cooled directly from the Space Station Freedom cooling water supply line, and then that water is directed through the rack heat exchanger and out through the SSF cooling water return. The furnace rack components are cooled by the SSFF internal water cooling loop. This concept is documented in "Space Station Furnace Facility Thermal Control System Conceptual Design", dated August 1991. While this concept remains an option, it was decided that for greater flexibility of the TCS subsystem, the SSFF TCS loop will be completely isolated from the module cooling loop so that custom coldplates can be used if necessary or desirable.

3.2 SELECTED CONCEPT

3.2.1 Description

The SSFF TCS water cooling loop collects heat from the furnace modules and SSFF subsystem electronics. The collected heat is then transferred to the Space Station Thermal Control System via the core rack heat exchanger. The schematic of the SSFF TCS is shown in Figure 3.2.1-1. During operation, coolant is directed in a single cooling line from the Coolant Pump Assembly outlet through the heat exchanger, then branches into a three-branch parallel system, each rack containing one cooling line. Each rack line branches into two parallel legs to flow through the coldplate mounted equipment, so that the TCS contains a total of six parallel legs, two in each rack. The cooling lines in the experiment racks rejoin into one line before the furnace modules so that the entire flow is available for cooling of the module. The three separate rack cooling lines rejoin into one line in the core rack, then the entire flow enters the Coolant Pump Assembly inlet. Estimated subsystems heat loads are shown in Table 3.2.1-1. The components of the SSFF TCS will be located in the the rear of the core rack behind the coldplate mounted SSFF Core electronics. The TCS consists of plumbing, fittings, sensors, and flow control components, packaged into Orbital Replacement Units (ORUs). A sketch of the SSFF TCS is shown in Figure 3.2.1-2, showing the ORUs, but omitting some of the core rack coldplates for clarity, as noted on the figure. Table 3.2.1-2 lists the separate Thermal Control Subsystem components and the performance requirements of each.

The water temperature in the SSFF TCS loop shall range from a minimum hot side outlet of 18.3 °C (inlet SSF cooling water temperature) to a hot side inlet temperature which allows the SSF cold side outlet temperature to be maintained at 50°C for a given heat load, unless the allocated SSF flow rate does not meet the SSFF requirements. If such a case occurs, SSFF will request the flow



* PUMP PACKAGE COMPONENTS ARE NUMBERED TCS PP-01-XX, BUT ONLY -XX IS SHOWN ON SCHEMATIC FOR CLARITY

FIGURE 3.2.1-1. SSFF THERMAL CONTROL SUBSYSTEM SCHEMATIC

TABLE 3.2.1-1. SSFF SUBSYSTEMS HEAT LOADS

WATER-COOLED: Subsystem Equipment (Quantity)	Heat Load (W)	Subtotal (W)
Thermal Control Subsystem:		
Coolant Pump Assembly (1)	132	
*Flow meters (4)	3	
*Flow Control Valves (4)	1	
*Temperature Sensors (11)	1	
*Pressure Transducers (5)	3	
*Shutoff Valves (4)	1	
		132
Gaseous Distribution Subsystem:		
Contamination Monitor (1)	150	
Compressors (2)	20	
		170
Data Management Subsystem:		
Furnace Control Unit (3)	309	
Furnace Actuator Unit (2)	240	
Core Control Unit (1)	155	
Removable Hard Drive (1)	84	
CD/ROM (1)	70	
High Density Recorder (1)	204	
Core Monitor and Control Unit (1)	43	
Video Processor (1)	145	
CPCS	88	
		1338
Power Conditioning and Distribution Subsystem:		
Core Power Distribution (1)	111	
Essentials Power Supplies (3)	386	
Core Power Conditioner (1)	1300	
		1797
****TOTAL SUBSYSTEM WATER-COOLED HEAT LOAD =**		**3437**
Furnace Module -1		1500
Furnace Module -2		2150
TOTAL SSFF WATER-COOLED HEAT LOAD =		**7087**

* Assume that on TCS valves, sensors, etc., half the heat is dissipated through the water cooling loop and half is dissipated through Avionics Air. Other subsystems' valves, etc., are cooled by Avionics Air only.

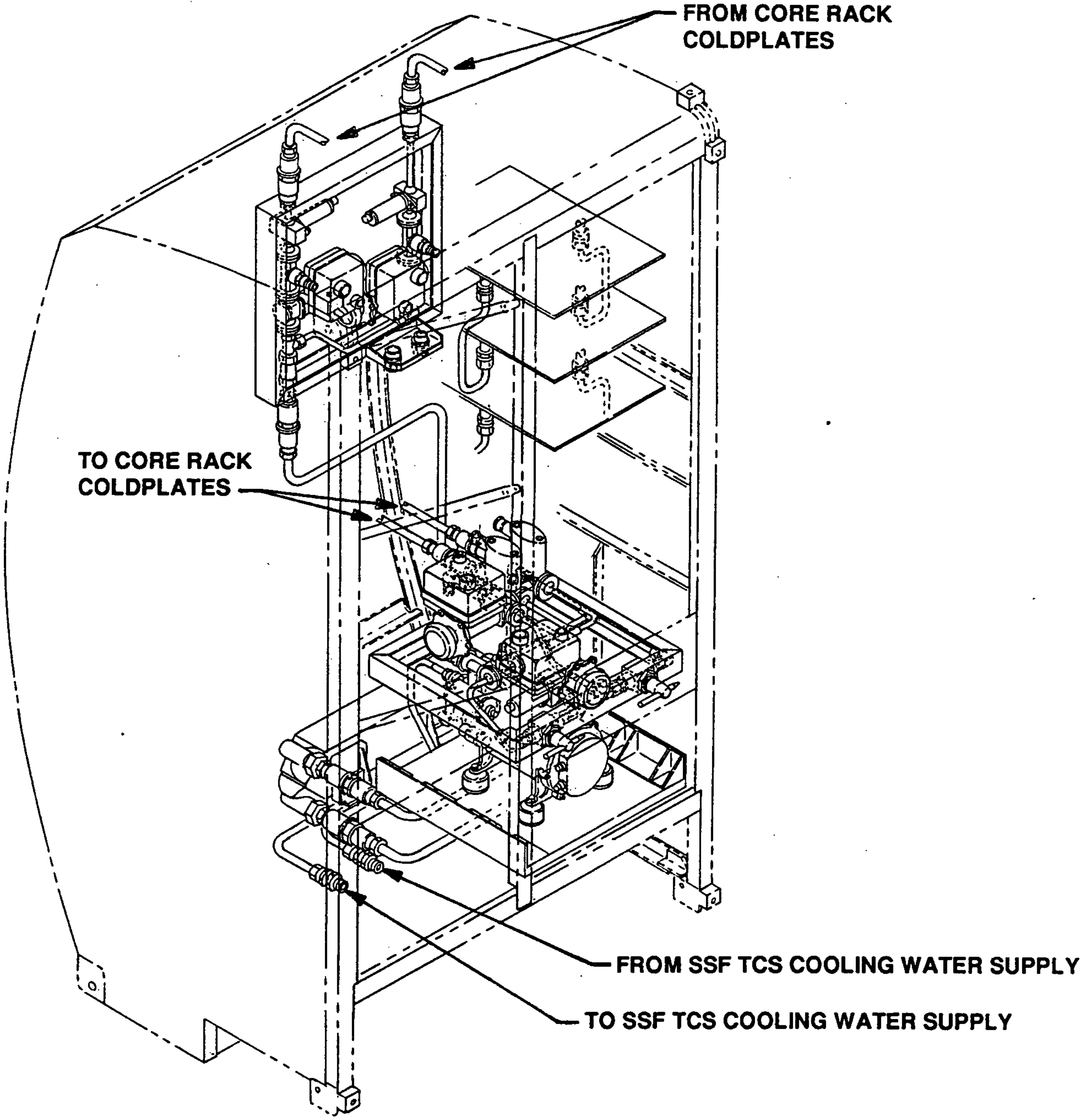
** Heat load from TCS valves, sensors, etc., is neglected in water cooling analysis since heat load from these is insignificant compared to total water-cooled heat load.

TABLE 3.2.1-1. SSFF SUBSYSTEMS HEAT LOADS (CONT.)

AVIONICS AIR-COOLED:

Subsystem Equipment (Quantity)	Heat Load (W)	Subtotal (W)
Thermal Control Subsystem:		
*Flow meters (4)	3	
*Flow Control Valves (4)	1	
*Temperature Sensors (11)	1	
*Pressure Transducers (5)	3	
*Shutoff Valves (4)	1	
		8
Gaseous Distribution Subsystem:		
Latching Solenoid Valves (16)	29	
Manual Valve (1)	2	
Pressure Transducers (3)	3	
Pressure Transducers (6)	12	
CM Sensors (4)	1	
		47
Data Management Subsystem:		
Crew Interface (1)	60	
DCMU (2)	96	156
Power Conditioning and Distribution Subsystem:		
Line and Connectors	639	
Current Pulsing Equipment (2)	80	
Furnace Power Distributors (2)	37	
Voltage/Current Sensors (136)	136	
		892
TOTAL SSFF AVIONICS AIR COOLED HEAT LOAD =		**1103**

* Assume that on TCS valves, sensors, etc., half the heat is dissipated through the water cooling loop and half is dissipated through Avionics Air. Other subsystems' valves, etc., are cooled by Avionics Air only.



NOTE: COLDPLATE DETAIL AND QUANTITY OMITTED FOR CLARITY

FIGURE 3.2.1-2. SKETCH OF SSFF TCS IN THE CORE RACK

TABLE 3.2.1-2. TCS COMPONENT PERFORMANCE REQUIREMENTS

Component Name	Schematic Number	Purpose	Operating Pressure Range	Temperature Range
Pressure Sensors	TCS PT-01 to TCS PT-05 and TCS PP-01-05 to TCS PP-01-06	water pressure sensor	0 to 689.5 kPa	16-50°C
Temperature Sensors	TCS TS-01 to TCS TS-11 and TCS PP-01-07	water temperature sensor	0 to 105 kPa	16-50°C
Flow Meters	TCS FM-01 to TCS FM-04	water flow sensor	0 to 689.5 kPa	16-50°C
Shutoff Valves	TCS SO-01 to TCS SO-04	Water Flow Shutoff	0 to 689.5 kPa	16-50°C
Manual Valves	TCS MV-01 to TCS MV-04	Manual Water Flow Shutoff	0 to 689.5 kPa	16-50°C
Coolant Pump Assembly	TCS PP-01	Water Flow	0 to 689.5 kPa	16-50°C
Check Valves	TCS CV-01 to TCS CV-04 and TCS PP-01-08 to TCS PP-01-09	Backflow Prevention into Pumps and lines	0 to 689.5 kPa	16-50°C
Filters	TCS PP-01-03 to TCS PP-01-04	Debris Prevention	0 to 689.5 kPa	16-50°C
Heat Exchanger	TCS HX-01	Heat Transfer to SSF Water	0 to 689.5 kPa	16-50°C
Flow Control Valve	TCS FCV-01 to TCS FCV-04	Water Flow Control	0 to 689.5 kPa	16-50°C
Bypass Relief Valve	TCS PP-01-11	Pressure relief in pump	0 to 689.5 kPa	16-50°C
Coldplates	TCS CP-01 to TCS CP-17	Heat transfer from avionics to TCS	103 to 621 kPa	16-50°C
Accumulators	TCS ACC-01 to TCS ACC-02	Volume compensator	0 to 689.5 kPa	16-50°C
Quick Disconnects	TCS QD-01 to TCS QD-64	Equipment connect/ disconnect	0 to 689.5 kPa	16-50°C

rate which allows the SSFF TCS temperatures to be within the design range, and the outlet temperature on the cold side will be below 50 °C. Calculations indicate that the SSFF TCS plumbing will have a nominal outside diameter of 0.9525 cm (0.375 in.) and a wall thickness of 0.089 cm (0.035 in.). A pressure drop in the system was calculated using this 3/8" line size, as shown in Table A-3 of Appendix A.

This configuration of the SSFF TCS has the capability of providing a total of 8000 watts of heat rejection for the core rack and up to two experiment racks. The total flow rate in the SSFF cooling loop was determined to be 272.2 kg/hr (600 lb/hr). This flow rate was chosen, since six parallel legs exist in the cooling loop and the flow will be divided into 45.4 kg/hr (100 lb/hr) through each leg, the minimum flow rate for which data is available on the heat exchanger and coldplates. The expected performance requirements of the TCS during and after exposure to the environment of the SSF Lab A module are specified in Table 3.2.1-3. Two maximum pump inlet temperatures are shown, one corresponding to the SSF allocated flow rate of 192.5 kg/hr determined by the SSFF heat load of 7087 W, and one corresponding to our requested SSF flow rate of 238.1 kg/hr, which allows the SSFF to maintain a maximum of 50 °C on the surface of the avionics coldplates.

The subsystem incorporates parallel flow between two coldplate branches in the core rack and two branches in each of the two experiment racks to allow independent service to each rack. The subsystem has the flow control capability to isolate any experiment rack from the system. A bypass loop is included in the system to maintain flow balancing. If a furnace is shut down for any reason, the flow through that experiment rack is diverted to the bypass loop until such time that the furnace needs cooling again.

3.2.2 Component Descriptions

Figure 3.2.2-1 shows the TCS component drawing tree. The lowest box level indicates TCS ORUs, with the components that make up the ORU listed underneath. The following paragraphs describe the TCS components and specification sheets are included in Appendix B with physical and performance information on each component.

The SSFF TCS shall interface with the Space Station Freedom Customer Thermal Control System water loop by one liquid-to-liquid heat exchanger. In this conceptual design, the standard WP-01 heat exchanger is used, since at the present time, payloads are only allowed to interface with SSF through this approved heat exchanger. The SSF standard heat exchanger has an 8000 watt capacity and in the SSFF TCS operates at a hot side flow rate of 272.5 kg/hr (600 lb/hr) with a design effectiveness of 0.86 and a design pressure drop of 3.44 kPa (0.5 psi). With the current worst case heat load of 7087 and an allocated SSF flow rate of 192.5 kg/hr (424.3 lb/hr), the effectiveness is 0.72. Each side of the heat exchanger will accommodate single loop flow with the

TABLE 3.2.1-3. SSFF TCS PERFORMANCE DATA

Maximum Heat Rejection Capability	8 kW
Operating Media	Water
Coolant Pump Assembly Accumulator Pressurant	Gaseous Nitrogen
Water Loop Flow Rate	272.2 kg/hr (600 lb/hr)
Water Temperature Range:	
Minimum Outlet	18.3°C (65 °F)
Maximum Inlet (with SSF allocated flow rate)	62.3°C (144 °F)
Maximum Inlet (with SSF requested flow rate)	47.1°C (117 °F)
Space Station Module Water Temp. Range:	
Inlet Range (non-selectable)	16°C - 18.3°C (61°F - 65°F) (NASA only)
Maximum Outlet	50°C (122 °F)
Maximum Operating Pressure	689.5 kPa (100 psi)
Fluid Leakage	< 1 cc/hr (0.06 in^3/hr)
Total Pressure Drop	< 206.8 kPa (30 psi)
Mass	< 200 kg

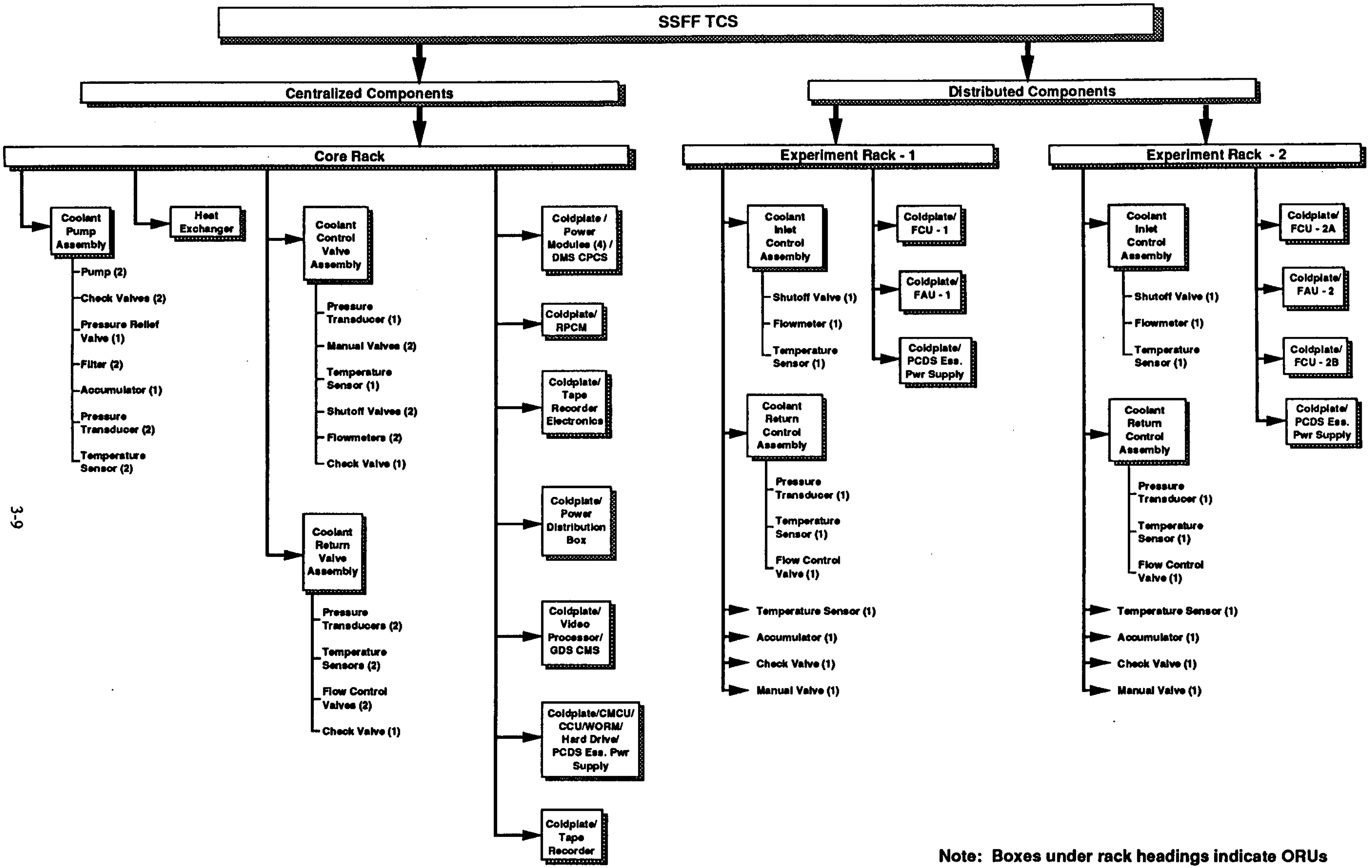
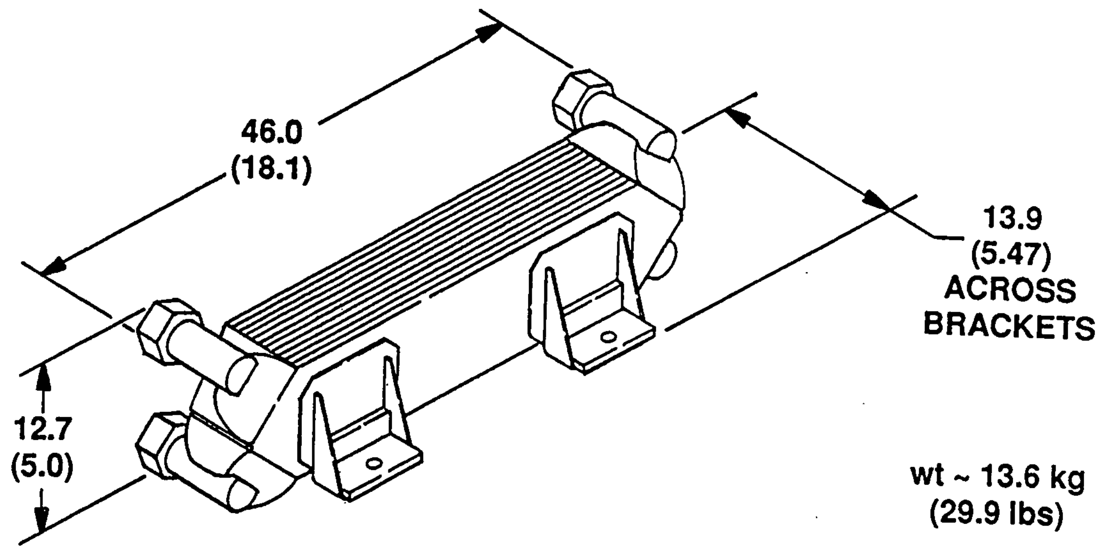


FIGURE 3.2.2-1. THERMAL CONTROL SUBSYSTEM COMPONENT TREE

SSFF equipment side being designated as the hot side and the U. S. Lab Module side being designated as the cold side. The envelope for the heat exchanger is shown in Figure 3.2.2-2. Table 3.2.2-1 gives the expected heat exchanger performance parameters to interface the integrated equipment with the module loop.

A combination of coldplates from WP-01 and custom-built coldplates are proposed for use in the SSFF Core rack and experiment racks to provide liquid cooling to the core electronics. The actual sizes of some of the electronics boxes to be cooled are TBD at this time because they will be custom built and the actual coldplate sizes will depend on those designs, but sizes have been estimated per current avionics envelopes. The physical envelope for the coldplates selected are given in Appendix B. Of the ten sizes of WP-01 coldplates available, the -5, and modified -7 are currently used in the SSFF design. The -7 coldplates will be modified slightly to provide the mounting surface on the opposite side of the manifold instead of the current configuration which has the manifold and mounting surface on the same side. Two custom-built coldplates are also used. The physical characteristics and performance parameters for these coldplates are given in Appendix B.

The Coolant Pump Assembly circulates the water through the loop, maintains system pressure and compensates for leakage and thermally induced volumetric changes. The Coolant Pump Assembly consists of two electrically powered positive displacement gear pumps with bypass relief valves, inlet filters, reverse flow check valves at the pump outlets, a system bypass relief valve, quick disconnects at the fluid loop interfaces and associated support structures. Each pump has a pumping capacity of a minimum of 272.2 kg/hr (600 lb/hr) at the resistances in the SSFF TCS water loop. Only one pump in the Coolant Pump Assembly operates at any one time, with the non-operating pump in the package acting as a backup in the event of failure. Sensors are included to monitor the fluid inlet temperature and inlet and outlet pressures. An accumulator is included in the Coolant Pump Assembly to compensate for normal thermal expansion within the water loop and to maintain positive water pump inlet pressure. A sensor in the Coolant Pump Assembly monitors the accumulator water quantity. Quick disconnects, designed to permit Coolant Pump Assembly removal and installation without filling and draining the fluid loop, are used to connect the Coolant Pump Assembly to the TCS. These disconnects are proposed to be self-sealing couplings of stainless steel construction with elastomeric seals. In these couplings, engagement of male and female halves begins with engagement of an external seal before the valve poppet is unseated permitting flow. Coupling halves are provided with non-integral dust seal caps. Filters to protect the Coolant Pump Assembly from debris shall be integrally mounted in the Coolant Pump Assembly assembly manifold upstream of the pump. The physical envelope for the Coolant Pump Assembly is defined in Figure 3.2.2-3. The performance parameters of the Coolant



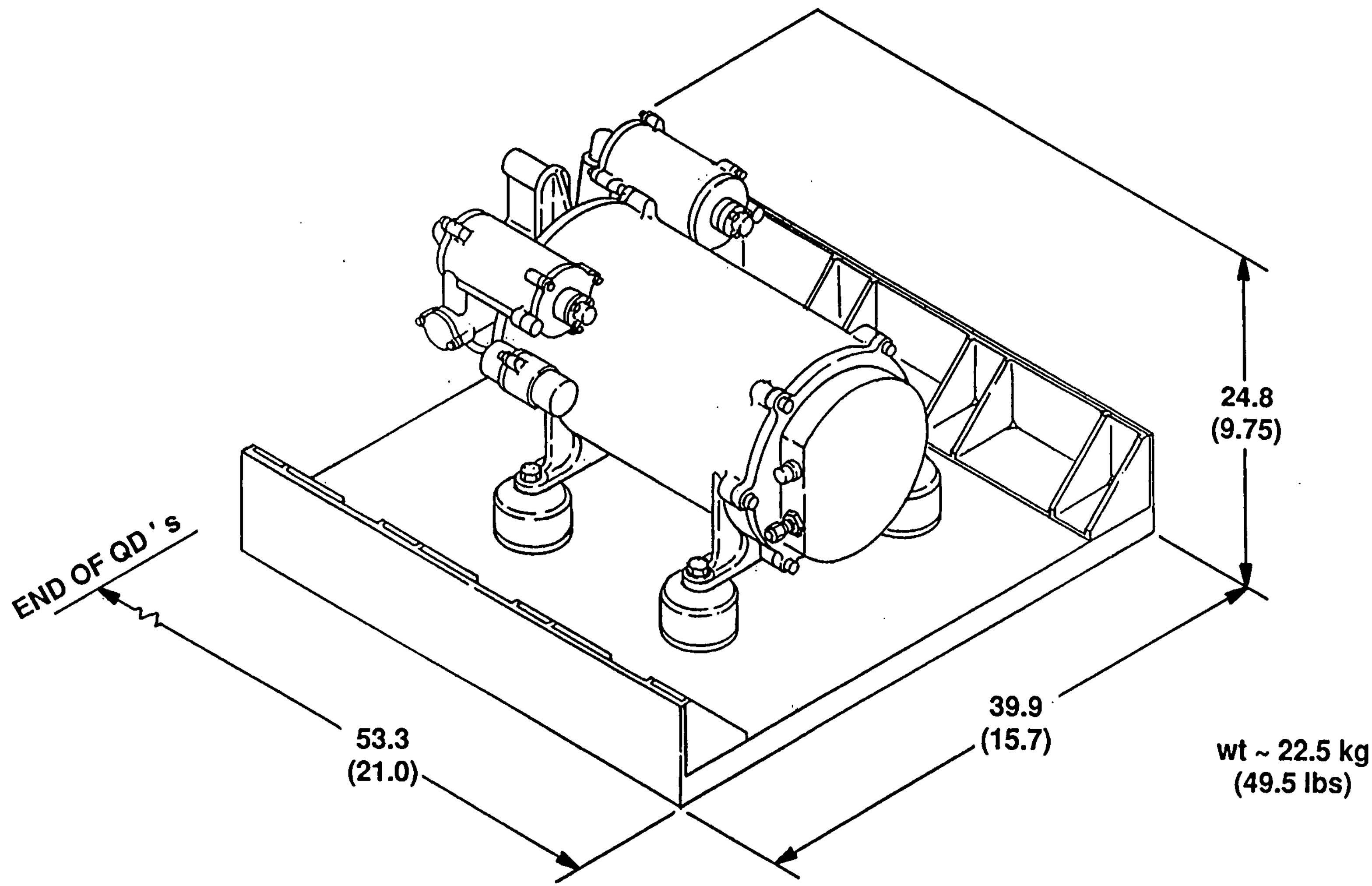
NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2-2. HEAT EXCHANGER ENVELOPE

TABLE 3.2.2-1. TCS HEAT EXCHANGER PERFORMANCE PARAMETERS*

Heat Transfer Capacity	8000 watts
Design Flow Rate (Hot and Cold Sides)	498.9 kg/hr
Inlet Temperature (hot side)	40.6°C
Outlet Temperature (cold side)	23.9°C
Effectiveness at Design Flow	0.86
Inlet Pressure	6.33 kg/cm^2 (abs)
Maximum Pressure Drop at Design Flow	0.035 kg/cm^2 (delta)
Leakage (External)	0.01 cc/hr
Leakage (Internal)	0.001 cc/hr
Collapse Pressure	2.27 kg/cm^2 (delta)
Proof Pressure	21.0 kg/cm^2 (delta)
Burst Pressure	28.0 kg/cm^2 (delta)

* Data taken from Rack Integration Manual, (D683-10475-1), January 1, 1991, Boeing Aerospace, Huntsville, Alabama.



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2-3. COOLANT PUMP ASSEMBLY ENVELOPE

Pump Assembly are given in Table 3.2.2-2. Heat dissipation by the Coolant Pump Assembly is estimated to be 132 W (nominal). This heat load will be accommodated by the SSFF TCS water loop.

Optimum flow in each leg of the SSFF cooling loop will be calculated for each mission's heat load and the flow through each loop will be reset if necessary prior to that mission. Flow control is maintained by flow control valves which regulate the amount of coolant flow through the core rack coldplates and the racks containing the furnace modules. This flow control system shall consist of an arrangement of electrically operated shutoff valves, manual valves, and flow control valves to control the flow, grouped together in ORUs as shown by the schematic in Figure 3.2.1-1 and the Component Tree in Figure 3.2.2-1. Two flow control assemblies are housed in the core rack; the Coolant Control Valve Assembly, shown in Figure 3.2.2-4, and the Coolant Return Valve Assembly, shown in Figure 3.2.2-5. Each experiment rack contains two assemblies; the Coolant Inlet Control Assembly, shown in Figure 3.2.2-6 and the Coolant Return Control Assembly, shown in Figure 3.2.2-7. The flow control ORUs are equipped with various instruments, as shown in Figures 3.2.2-4 through 3.2.2-7, including sensors to monitor temperatures and pressures of the water supplied to each branch, flow meters to measure the flow of water at various points in the loop to provide flow proportioning information for monitoring flow control, flow control valves to control flow to each leg of the cooling loop and adjust the flow as necessary for each new mission heat load, check valves to prevent backflow of water through the furnace modules and core rack coldplates, and hand operated valves to provide manual shutoff when necessary. Referring to Figure 3.2.1-1, each branch leaving the heat exchanger, except the core coldplate branch, shall have a hand operated valve for shut-off. These manual valves shall be located such that they are easily accessible by the crew.

Each experiment rack is equipped with an accumulator for use in the event of overpressurization of water in the furnace cooling or loss of cooling.

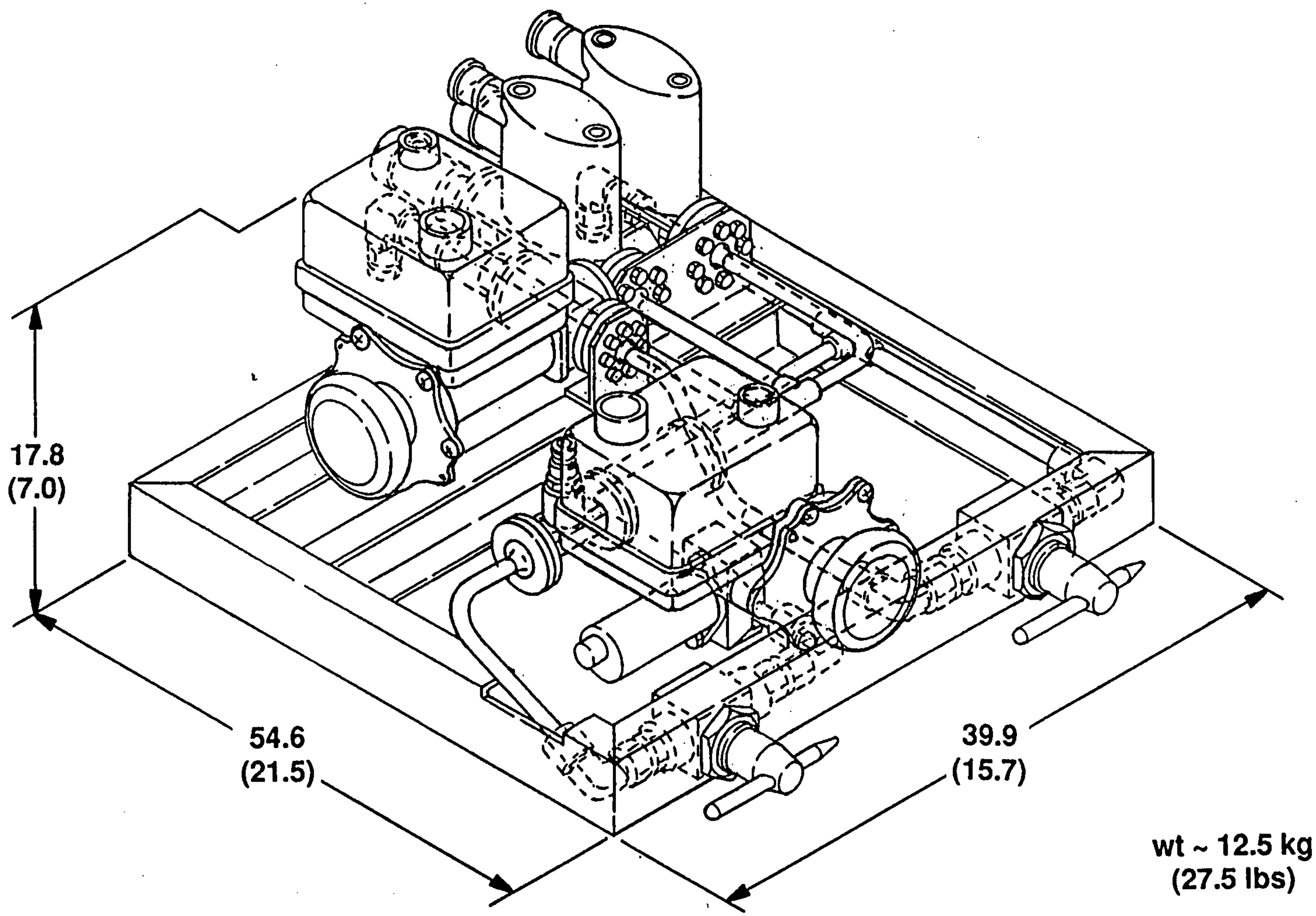
3.3 SAFETY

The Thermal Control Subsystem has no identifiable safety concerns other than those normally associated with this type of system. Typical hazards and controls to be addressed are listed below:

- Release of water into cabin, furnace, etc.. Prevented by appropriate design safety margins based on maximum design pressure (MDP) for all plumbing components.
- Fail-safe design for loss of cooling to control potential hazards of fire, overpressurization and touch temperature exceedances. Controls will include automatic removal of electrical power when loss of cooling is sensed and use of accumulator to accommodate any boiling or vaporization of water from an overheated furnace.

TABLE 3.2.2-2. TCS COOLANT PUMP ASSEMBLY PERFORMANCE PARAMETERS

Normal Inlet Conditions:	
Fluid Temperature	62 °C
Pressure	172.4 - 1206.6 kPa
Flow Rate	272.2 kg/hr
Accumulator Capacity	3392 cm^3
Instrumentation:	
Accumulator Quantity Sensor	
System Inlet Pressure Sensor	
System Outlet Pressure Sensor	
System Outlet Temperature Sensor	
Pump Bypass Relief Valve	
System Bypass Relief Valve	
Voltage	115/200 VAC, 400 Hz
Power (max)	132 watts
Mass (dry)	15.9 kg
Envelope (l x w x h)	38 cm x 25 cm x 20 cm
Operating Media	Water



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2-4. CORE RACK COOLANT CONTROL VALVE ASSEMBLY

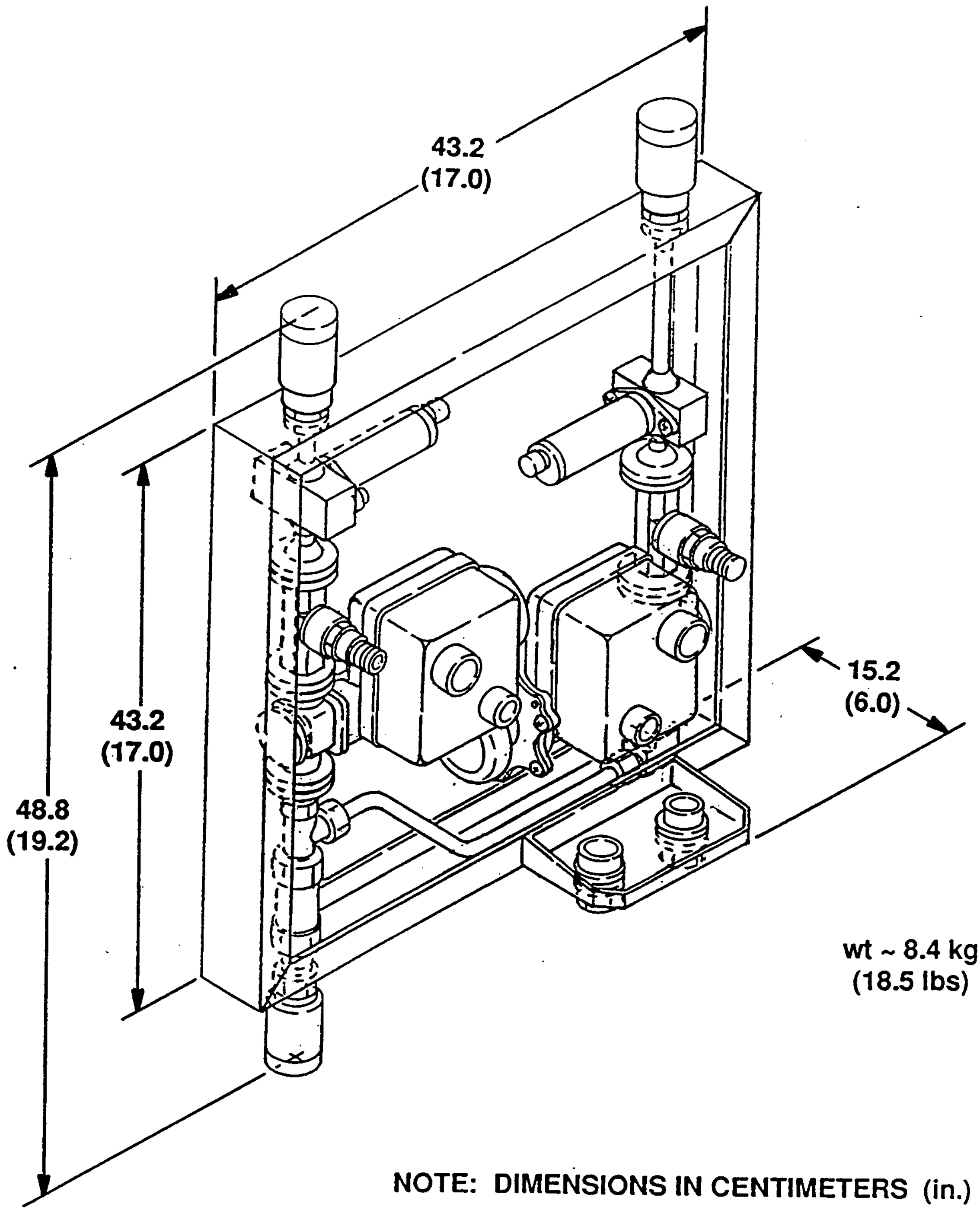


FIGURE 3.2.2-5. CORE RACK COOLANT RETURN VALVE ASSEMBLY

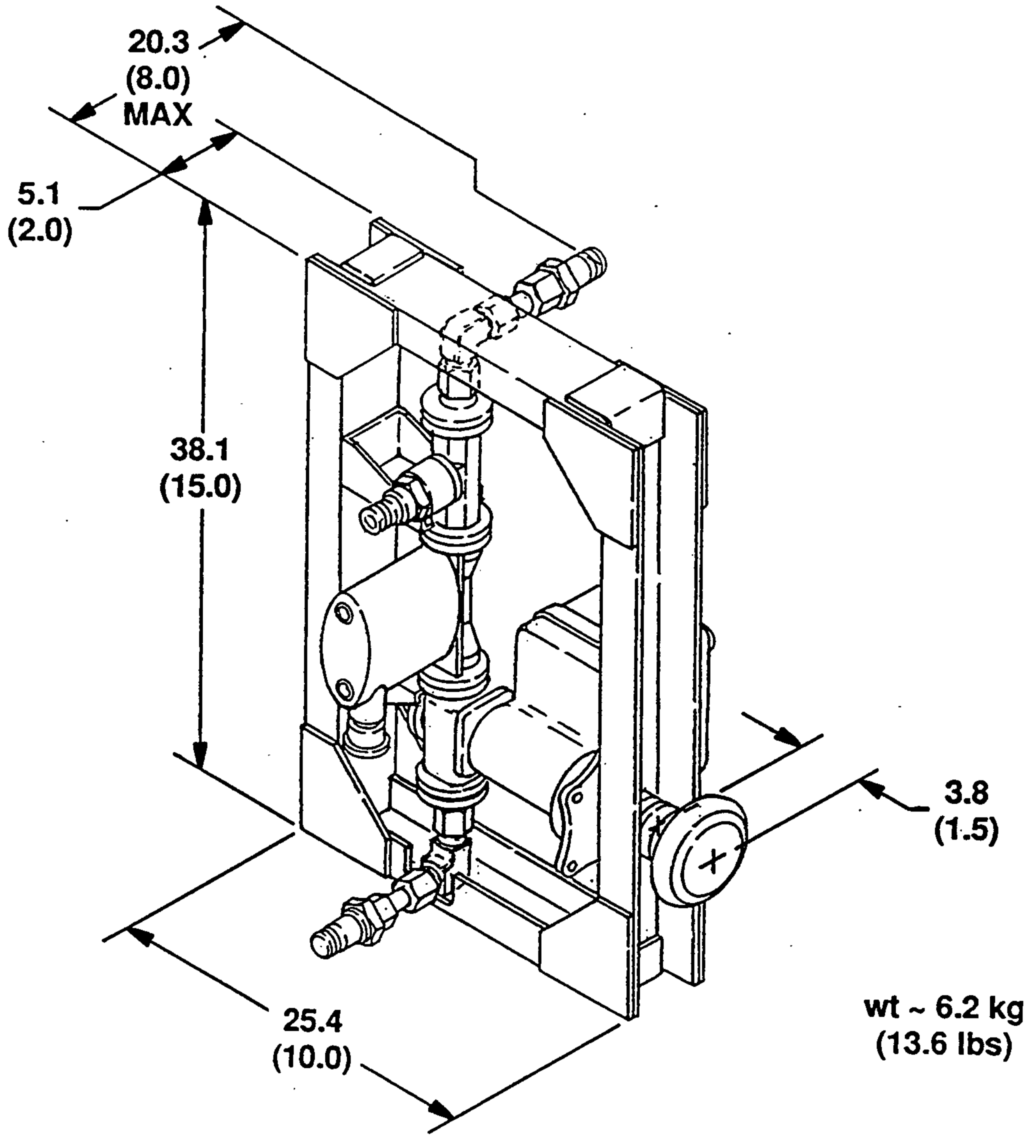


FIGURE 3.2.2-6. EXPERIMENT RACK COOLANT INLET CONTROL ASSEMBLY

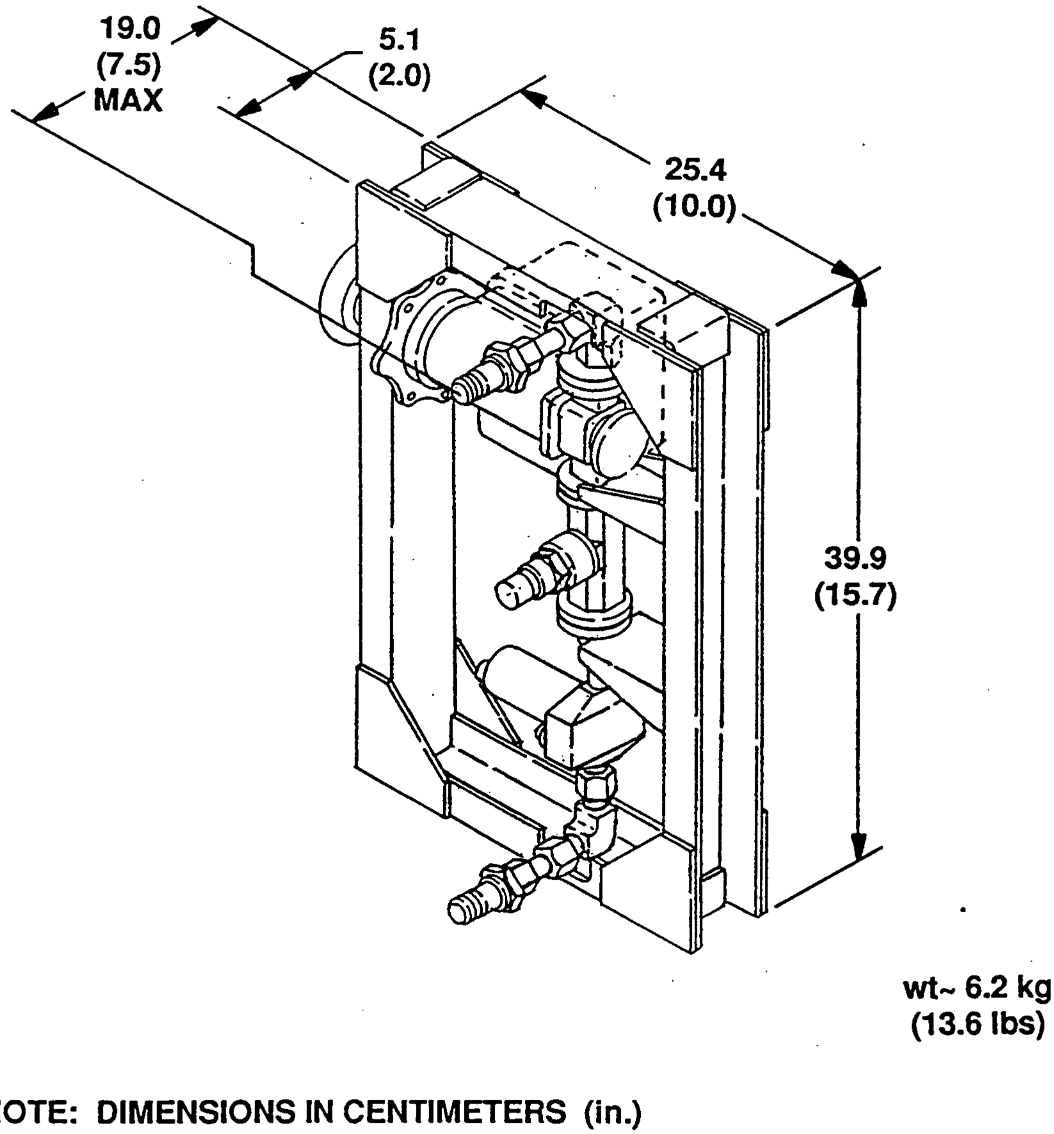


FIGURE 3.2.2-7. EXPERIMENT RACK COOLANT RETURN CONTROL ASSEMBLY

- Touch temperature control for surfaces accessible to the crew during normal and contingency operations. During normal operations, active cooling should maintain surface temperatures below 45°C. For contingency operations (e.g., loss of cooling, furnace re-entry), temperature indicator labels, malfunction/operational procedures with warnings, sample cooldown times as determined by test, etc., are appropriate hazard control measures.

- Structural failure of rotating devices (e.g., pumps) with possible release of fragments. Containment devices, protective devices such as thermal overload sensors and over-speed control, plus adequate structural design including application of fracture control requirements, are appropriate control measures.

4.0 RESOURCE REQUIREMENTS

The resource requirements of the Thermal Control Subsystem were estimated and are discussed below. These resources are presented for the configuration shown in Figure 3.2.1-1.

4.1 POWER

The TCS utilizes Space Station Furnace Facility power allocated as shown in Table 4.1-1. Power conditioning is accomplished in the SSFF core rack by the SSFF Power Conditioning and Distribution Subsystem (PCDS). The TCS active components will be manually or remotely operated by the Core Monitor and Control Unit (CMCU) to support automatic or man-tended operations.

4.2 MASS AND VOLUME

The mass and volume of the equipment in the TCS was estimated from preliminary vendor data on equipment proposed for use and the common equipment in WP-01 as shown in Appendix B. Table 4.2-1 summarizes the mass properties of the components of the TCS.

4.3 THERMAL

Heat dissipation by the Coolant Pump Assembly is estimated to be 132 W. This heat load will be accommodated by the TCS water loop. Half the heat dissipated by the electric sensors and electromechanical valves is estimated to be accommodated by the SSFF TCS water loop, and half by SSF Avionics Air. The thermal requirements of the TCS are shown in Table 4.3-1.

4.4 DMS

The TCS will require several interfaces to the DMS subsystem for control of the following operations: start-up, standard operation, emergency safing, maintenance/reconfiguration, and shutdown/securing. Under standard conditions, the TCS will require minimum crew interaction (manual valves must be configured to enter or leave a secured condition). The DMS system will monitor all valves, sensors, the Coolant Pump Assembly, and verification systems within the TCS. Table 4.4-1 shows the TCS DMS Requirements.

4.5 STRUCTURAL

The TCS components will require adequate mounting structures within the racks for virtually all the components in order to survive the flight and ground handling loads.

4.6 OTHERS

No other resource requirements are identified at this time.

TABLE 4.1-1. TCS POWER REQUIREMENTS

Component	Qty	Power Each (watts)	Voltage	Total Power (watts)
Coolant Pump Assembly	1	132.0	115/200 VAC, 400 Hz	132.0
Shutoff Valves	4	7.0	120 VDC	28.0
Flow Meters	4	1.5	±12 VDC	6.0
Flow Control Valves	4	7.0	120 VDC	28.0
Pressure Sensors	5	1.2	±12 VDC	5.8
Temperature Sensors	11	0.1	20 mv/°F	1.3
Total Power:				**201.1**

TABLE 4.2-1. TCS MASS AND VOLUME

Package	Qty	Unit Mass (kg)	Total Mass (kg)	Pkg Mass (kg)	Unit Volume (cm^3)	Total Volume (cm^3)	Pkg Volume (cm^3)
Centralized Equipment:							
Heat Exchanger	1	13.6	13.6		10573	10573	
Coolant Pump Assembly	1	15.9	15.9		19050	19050	
Flow Meters	2	0.8	1.5		229	459	
Flow Control Valves	2	1.9	3.7		2793	5587	
Temperature Sensors	5	0.1	0.5		46	227	
Pressure Transducers	3	0.5	1.5		168	506	
Custom Coldplates	4	6.0	24.0		1290	5160	
-5 Coldplates	2	1.6	3.3		251	503	
Pwr Mod Coldplate-Upper	2	6.0	12.0		1290	2580	
Pwr Mod Coldplate-Lower	2	4.9	9.8		1104	2208	
Plumbing	25 m	0.5/m	13.6		2268	56704	
Quick Disconnects	30	0.1	3.0		59	1781	
Check Valves	2	0.1	0.1		32	65	
Manual Valves	2	0.1	0.3		63	126	
Shutoff Valves	2	1.9	3.7		2793	5587	
Water		10.0	<u>10.0</u>				
				116.5			111114
Distributed Equipment:							
Modified -7 Coldplates	7	3.9	27.3		578	4050	
Temperature Sensors	6	0.1	0.5		46	273	
Pressure Transducers	2	0.5	1.0		168	337	
Flow Meters	2	0.8	1.5		229	459	
Flow Control Valve	2	1.9	3.7		2793	5587	
Check Valves	2	0.1	0.1		32	65	
Manual Valves	2	0.1	0.3		63	126	
Shutoff Valves	2	1.9	3.8		2793	5587	
Plumbing	25 m	0.5/m	13.6		2268	56704	
Accumulators	2	2.7	5.4		3791	7582	
Quick Disconnects	34	0.1	3.4		59	2018	
Water		14.0	<u>14.0</u>				
				<u>74.6</u>			<u>82786</u>
TOTAL MASS (kg)				**191.3**			
TOTAL VOLUME (cm^3)							**193900**

TABLE 4.3-1. TCS THERMAL REQUIREMENTS

Component	Qty	Max Load Each (watts)	Total Thermal Load (watts)	Cooling Method
Coolant Pump Asembly	1 (2 pumps)	132.0	132.0	SSFF water cooling
Pressure Sensor	5	1.2	5.8	1/2 SSFF water cooling/ 1/2 Avionics Air
Flow Meter	4	1.5	6.0	1/2 SSFF water cooling/ 1/2 Avionics Air
Flow Control Valve	4	0.35	1.4	1/2 SSFF water cooling/ 1/2 Avionics Air
Shutoff Valve	4	0.35	1.4	SSFF water cooling/ 1/2 Avionics Air
Temperature Sensor	11	0.12	1.3	1/2 SSFF water cooling/ 1/2 Avionics Air
Total Thermal Load - SSFF Water Cooled			**139.9**	
Total Thermal Load - Avionics Air Cooled			**7.9**	

TABLE 4.4-1. TCS DMS REQUIREMENTS

COMPONENT NAME	SCHEMATIC NUMBER	QTY	SIGNAL TYPE	SIGNAL PURPOSE	RATE (samples/sec)	BIT CONV.
Pressure Sensors	TCS PT-01 to TCS PT-05	5	1 analog input per sensor 1 analog output per sensor	sense pressure	1	8
Flow Meters	TCS FM-01 to TCS FM-04	4	2 analog inputs per sensor 1 analog output per sensor	sense flow	1	8
Temperature Sensors	TCS TS-01 to TCS TS-11	11	4 wire resistance measurement (RTD)	sense temperature	1	8
Shutoff Valves	TCS SO-01 to TCS SO-04	4	1 discrete input 3 discrete outputs	Flow on/off	1	discrete (closure)
Pump Package	TCS PP-01	1	Qty-analog voltage (potentiometer) 0-5.1Vdc (±3% accuracy) Temp-RTD source, analog voltage 0-5.1Vdc (±1psia) Press-strain gauge, 4 wire interface	sense accumulator quantity sense temperature across package sense pressure across package	1	8
Flow Control Valves	TCS FCV-01 to TCS FCV-04	4	4 discrete inputs 4 discrete outputs	control flow	1	8

5.0 ISSUES AND CONCERNS

Issues and concerns for the TCS include the following:

1. SSF-Allocated Flowrate

   The SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet temperature. For the current SSFF heat load of 7087 W, the SSF cooling water flow to the SSFF core rack will not be sufficient to maintain the 50°C coldplate surface temperature to all coldplates in the core rack. This concern is documented and explained in more detail in the memorandum, "Space Station Freedom (SSF) Thermal Control System (TCS) Allocations", APD91-023.

   Per the Payload Accommodations Handbook, SS-HDBK-0001, "The RFCA can maintain either a specific flow rate or a specific outlet temperature as determined by the user. Both modes of control will be available for any particular application, but only one mode may be active at any one time at a specific location.". Realistically, the SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet temperature, but if the user's experiment temperature is out of limits, he may request a higher flow rate than that which is allocated to him. To achieve the optimum effectiveness of the payload heat exchanger, the cold side flow rate and hot side flow rate should match, but requesting 272 kg/hr for a single payload when the total Lab-A flow rate allocated to all payloads is 500 kg/hr may be unreasonable.

2. Payload Heat Exchanger Limitation

   The current maximum capacity of the SSFF TCS is 8 kW, since the heat exchanger approved for payload use to interface with the SSF TCS is limited to 8 kW. Since the core rack will reside in a 12 kW rack location, the possibility exists that up to 12 kW will need to be dissipated at one time, indicating the need for another heat exchanger and possibly a Coolant Pump Assembly. The impacts to SSFF would be an increase in volume and mass due to more TCS components in the rack. At this time, analysis shows that one heat exchanger is adequate, since the heat load is currently less than 8 kW.

APPENDIX A
TRADES AND ANALYSES

TABLE A-1. LINE AND COLDPLATE TEMPERATURE CALCULATION SPREADSHEET FOR SSF ALLOCATED FLOWRATE

Nomenclature used in this spreadsheet is from the current TCS schematic.
Enter all data needed in the shaded boxes below.

Cold side flow rate (TCS side) kg/hr=	192.5	424.3 lb/hr
Hot side flow rate (Core side) kg/hr=	272.2	600.0 lb/hr
T1 (TCS Supply Temp) °C=	18.3	18.3 °C
Flow rate in 1st Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr

Enter effectiveness of Heat Exchanger: 0.72

Note: Effectiveness is found on Pg 103 of RIM and depends on SSF side and Core side flow rates.

Note: U is specified for a certain branch flow rate and a certain size coldplate in RIM:

Enter U from Pg 98 of RIM for coldplate 5-1	(TCS CP-11)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 5-2	(TCS CP-12)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 5-3	(TCS CP-13)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-1	(TCS CP-01)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-2	(TCS CP-02)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-3	(TCS CP-03)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-4	(TCS CP-04)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-1	(TCS CP-05)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-2	(TCS CP-06)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-3	(TCS CP-07)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-4	(TCS CP-08)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-5	(TCS CP-09)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-6	(TCS CP-10)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-1	(TCS CP-14)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-2	(TCS CP-15)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-3	(TCS CP-16)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-4	(TCS CP-17)	1.3	W / in^2-°F

Area of Coldplates (in^2):

CP 5-1 (-3) =	240	in^2
CP 5-2 (-3) =	240	in^2
CP 5-3 (-3) =	240	in^2
CP 6-1 (custom) =	408	in^2
CP 6-2 (custom) =	408	in^2
CP 6-3 (custom) =	408	in^2
CP 6-4 (custom) =	408	in^2
CP 7-1 (-5) =	76.7	in^2
CP 7-2 (-5) =	76.7	in^2
CP 7-3 (custom) =	338	in^2
CP 7-4 (custom) =	338	in^2
CP 7-5 (custom) =	408	in^2
CP 7-6 (custom) =	408	in^2
CP 8-1 (-3) =	240	in^2
CP 8-2 (-3) =	240	in^2
CP 8-3 (-3) =	240	in^2
CP 8-4 (-3) =	240	in^2

Heat Loads on the different coldplates (W):

Q for Coldplate 5 - 1 =	120	W
Q for Coldplate 5 - 2 =	103	W
Q for Coldplate 5 - 3 =	90	W
Q for Coldplate 6 - 1 =	500	W
Q for Coldplate 6 - 2 =	194	W
Q for Coldplate 6 - 3 =	557.3	W
Q for Coldplate 6 - 4 =	70	W
Q for Coldplate 7 - 1 =	37.4	W
Q for Coldplate 7 - 2 =	73.9	W
Q for Coldplate 7 - 3 =	194	W
Q for Coldplate 7 - 4 =	500	W
Q for Coldplate 7 - 5 =	295	W
Q for Coldplate 7 - 6 =	134	W
Q for Coldplate 8 - 1 =	120	W
Q for Coldplate 8 - 2 =	103	W
Q for Coldplate 8 - 3 =	90	W
Q for Coldplate 8 - 4 =	103	W
Q for Compressor in Exp. Rack -1 =	10	W
Q for Compressor in Exp. Rack -2 =	10	W
Q for Pump Package =	132	W

Heat Loads from Furnaces (W):

CGF	1500	W
PMZF	2150	W

Results of Thermal Analysis

Total Heat Rejection (Watts) = 7086.6
Flow Allocation: Cold Side (kg/hr) = 192.5
Hot Side (kg/hr) = 272.2

Temperatures at Different Points:

T1 (°C)	18.3
T2 (°C)	50.0
T3 (°C)	62.3
T4 (°C)	39.9
T5 (°C)	39.9
T5A1 (°C)	42.2
T5A2 (°C)	44.2
T5B1 (°C)	41.6
T5B2 (°C)	41.8
T5C (°C)	43.0
T5D (°C)	57.2
T6 (°C)	39.9
T6A (°C)	49.4
T6B (°C)	53.1
T6C (°C)	63.7
T6D (°C)	65.0
T7 (°C)	39.9
T7A (°C)	40.6
T7B (°C)	42.0
T7C (°C)	45.7
T7D (°C)	55.2
T7E (°C)	60.8
T7F (°C)	63.3
T8 (°C)	39.9
T8A1 (°C)	42.2
T8B1 (°C)	44.2
T8A2 (°C)	41.6
T8B2 (°C)	43.6
T8B3 (°C)	43.8
T8C (°C)	43.9
T8D (°C)	64.3
T9 (°C)	61.9

Surface Temperatures of Coldplates:

Ts 5-1 (°C)	42.2
Ts 5-2 (°C)	44.2
Ts 5-3 (°C)	41.6
Ts 6-1 (°C)	49.4
Ts 6-2 (°C)	53.1
Ts 6-3 (°C)	63.7
Ts 6-4 (°C)	65.0
Ts 7-1 (°C)	40.6
Ts 7-2 (°C)	42.1
Ts 7-3 (°C)	45.7
Ts 7-4 (°C)	55.2
Ts 7-5 (°C)	60.8
Ts 7-6 (°C)	63.3
Ts 8-1 (°C)	42.2
Ts 8-2 (°C)	44.2
Ts 8-3 (°C)	41.6
Ts 8-4 (°C)	43.6

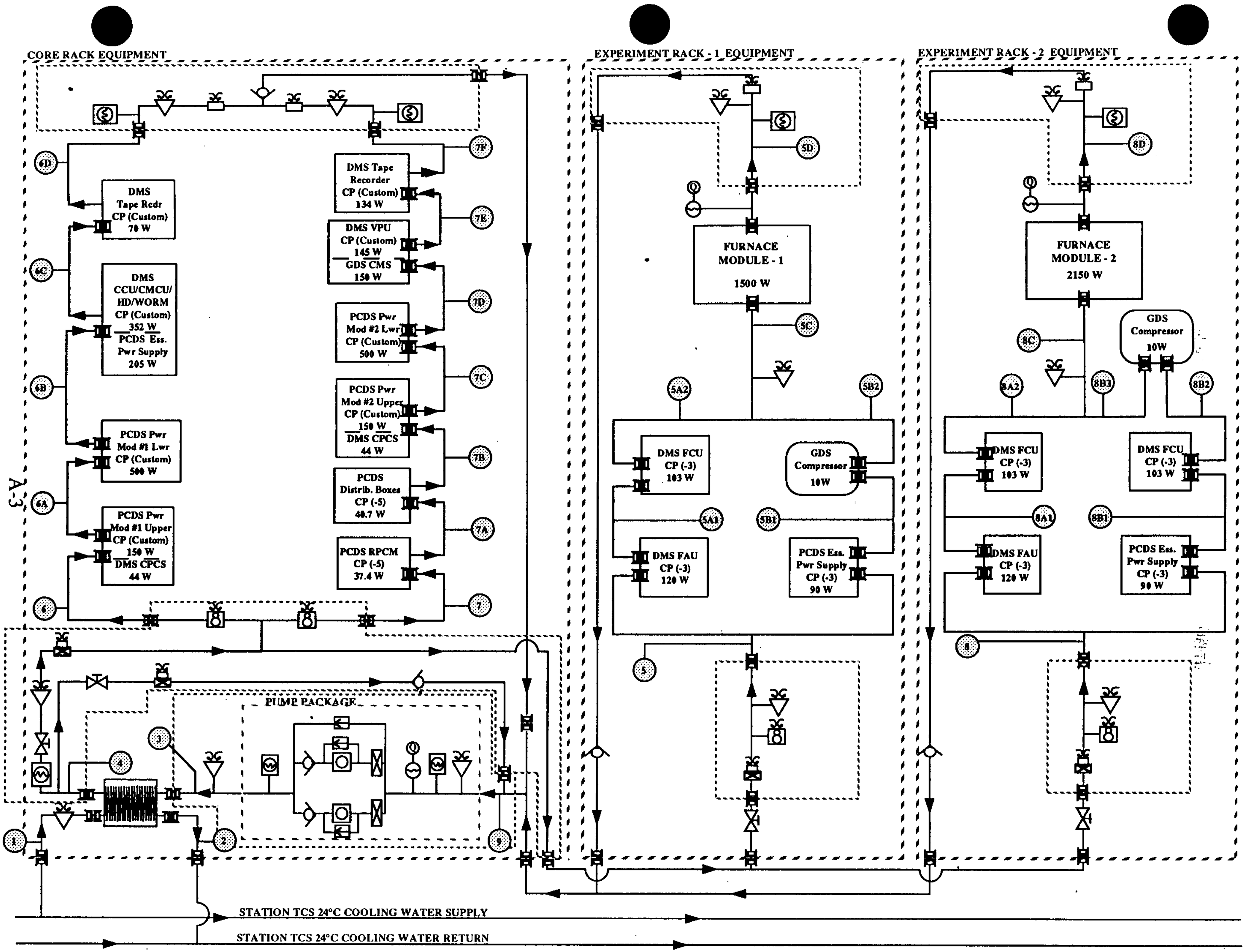


FIGURE A-1. SSFF TCS SCHEMATIC WITH CALCULATED TEMPERATURE LOCATIONS

TABLE A-2. LINE AND COLDPLATE TEMPERATURE CALCULATION SPREADSHEET FOR SSF REQUESTED FLOWRATE

Nomenclature used in this spreadsheet is from the current TCS schematic.
Enter all data needed in the shaded boxes below.

Cold side flow rate (TCS side) kg/hr=	238.1	525.0 lb/hr
Hot side flow rate (Core side) kg/hr=	272.2	600.0 lb/hr
T1 (TCS Supply Temp) °C=	18.3	18.3 °C
Flow rate in 1st Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr

Note: U is specified for a certain branch flow rate and a certain size coldplate in RIM:

Enter U from Pg 98 of RIM for coldplate 5-1	(TCS CP-11)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 5-2	(TCS CP-12)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 5-3	(TCS CP-13)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-1	(TCS CP-01)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-2	(TCS CP-02)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-3	(TCS CP-03)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 6-4	(TCS CP-04)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-1	(TCS CP-05)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-2	(TCS CP-06)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-3	(TCS CP-07)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-4	(TCS CP-08)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-5	(TCS CP-09)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 7-6	(TCS CP-10)	1.5	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-1	(TCS CP-14)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-2	(TCS CP-15)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-3	(TCS CP-16)	1.3	W / in^2-°F
Enter U from Pg 98 of RIM for coldplate 8-4	(TCS CP-17)	1.3	W / in^2-°F

Enter effectiveness of Heat Exchanger: 0.89

Note: Effectiveness is found on Pg 103 of RIM and depends on SSF side and Core side flow rates.

Area of Coldplates (in^2):

CP 5-1 (-3) =	240	in^2
CP 5-2 (-3) =	240	in^2
CP 5-3 (-3) =	240	in^2
CP 6-1 (custom) =	408	in^2
CP 6-2 (custom) =	408	in^2
CP 6-3 (custom) =	408	in^2
CP 6-4 (custom) =	408	in^2
CP 7-1 (-5) =	76.7	in^2
CP 7-2 (-5) =	76.7	in^2
CP 7-3 (custom) =	338	in^2
CP 7-4 (custom) =	338	in^2
CP 7-5 (custom) =	408	in^2
CP 7-6 (custom) =	408	in^2
CP 8-1 (-3) =	240	in^2
CP 8-2 (-3) =	240	in^2
CP 8-3 (-3) =	240	in^2
CP 8-4 (-3) =	240	in^2

Heat Loads on the different coldplates (W):

Q for Coldplate 5 - 1 =	120	W
Q for Coldplate 5 - 2 =	103	W
Q for Coldplate 5 - 3 =	90	W
Q for Coldplate 6 - 1 =	500	W
Q for Coldplate 6 - 2 =	194	W
Q for Coldplate 6 - 3 =	557.3	W
Q for Coldplate 6 - 4 =	70	W
Q for Coldplate 7 - 1 =	37.4	W
Q for Coldplate 7 - 2 =	73.9	W
Q for Coldplate 7 - 3 =	194	W
Q for Coldplate 7 - 4 =	500	W
Q for Coldplate 7 - 5 =	295	W
Q for Coldplate 7 - 6 =	134	W
Q for Coldplate 8 - 1 =	120	W
Q for Coldplate 8 - 2 =	103	W
Q for Coldplate 8 - 3 =	90	W
Q for Coldplate 8 - 4 =	103	W
Q for Compressor in Exp. Rack -1 =	10	W
Q for Compressor in Exp. Rack -2 =	10	W
Q for Pump Package =	132	W

Heat Loads from Furnaces (W):

CGF	1500	W
PMZF	2150	W

Results of Thermal Analysis

Total Heat Rejection (Watts) = 7086.6
Flow Allocation: Cold Side (kg/hr) = 238.1
Hot Side (kg/hr) = 272.2

Temperatures at Different Points:

T1 (°C)	18.3
T2 (°C)	43.9
T3 (°C)	47.1
T4 (°C)	24.7
T5 (°C)	24.7
T5A1 (°C)	27.0
T5A2 (°C)	28.9
T5B1 (°C)	26.4
T5B2 (°C)	26.6
T5C (°C)	27.8
T5D (°C)	42.0
T6 (°C)	24.7
T6A (°C)	34.2
T6B (°C)	37.9
T6C (°C)	48.4
T6D (°C)	49.8
T7 (°C)	24.7
T7A (°C)	25.4
T7B (°C)	26.8
T7C (°C)	30.5
T7D (°C)	40.0
T7E (°C)	45.6
T7F (°C)	48.1
T8 (°C)	24.7
T8A1 (°C)	27.0
T8B1 (°C)	28.9
T8A2 (°C)	26.4
T8B2 (°C)	28.4
T8B3 (°C)	28.5
T8C (°C)	28.6
T8D (°C)	49.0
T9 (°C)	46.7

Surface Temperatures of Coldplates:

Ts 5-1 (°C)	27.0
Ts 5-2 (°C)	28.9
Ts 5-3 (°C)	26.4
Ts 6-1 (°C)	34.2
Ts 6-2 (°C)	37.9
Ts 6-3 (°C)	48.4
Ts 6-4 (°C)	49.8
Ts 7-1 (°C)	25.4
Ts 7-2 (°C)	26.8
Ts 7-3 (°C)	30.5
Ts 7-4 (°C)	40.0
Ts 7-5 (°C)	45.6
Ts 7-6 (°C)	48.1
Ts 8-1 (°C)	27.0
Ts 8-2 (°C)	28.9
Ts 8-3 (°C)	26.4
Ts 8-4 (°C)	28.4

TABLE A-3. SSFF TCS PRESSURE DROP CALCULATION SPREADSHEET

Pressure Drop:	kPa	psi
Core Rack	142.65	20.69
Furnace Module-1	12.12	1.76
Furnace Module-2	12.77	1.85
Total	167.54	24.30

Total Mdot-Hot Side of HTX (kg/hr):	272.2	600.00 lb/hr
Mdot for CP-01 to CP-04 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-05 to CP-10 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-11 to CP-12 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-13 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-14 to CP-15 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-16 to CP-17 (kg/hr):	45.4	100.00 lb/hr
Pressure Drop for Furnace Module-1 (kPa):	4.8	0.70 psi
Pressure Drop for Furnace Module-2 (kPa):	4.8	0.70 psi

Enter the number of each of the components in the shaded boxes. The pressure drop per component is in parentheses.
Note: Only add the number of components on one branch in the Core and leave out components in bypass.

	Core Line Parallel Flow	Core Line Total Flow	Exp Rack-1	Exp Rack-2	Total
Heat Exchanger (0.5 psi @ 1000lbs/hr)	0	1	0	0	1
Pump Package (1 psi)	0	1	0	0	1
Flow Meters (0.1 psi @ 100lbs/hr)	1	0	1	1	3
Flow Control Valves (0.25 psi @ 1230lbs/hr)	1	0	1	1	3
Temperature Sensors (1 ft equiv. length)	2	1	3	3	9
Pressure Transducers (1 ft equiv. length)	1	0	1	1	3
Coldplates (0.6 psi @ 1000lbs/hr)	6	0	2	2	10
Check Valves (0.3 psi @ 100lbs/hr)	1	0	1	1	3
Manual Valves (0.3 psi @ 100lbs/hr)	0	1	1	1	3
Shutoff Valves (3.5 psi @ 630lbs/hr)	0	1	1	1	3
Total Length of Line (inches):	171	73	104	148	
meters (refer to Assumption #8):	13.03	5.56	7.92	11.28	

Individual Pressure Drops are in psi.

	Pressure Drop HTX	Pressure Drop Pump Pkg.	Pressure Drop Flow Meters	Pressure Drop Flow Control V
Core-Parallel Flow	0.00	0.0	0.1	0.002
Core-Total Flow	0.18	1.0	0.0	0.000
Experiment Rack-1	0.00	0.0	0.1	0.002
Experiment Rack-2	0.00	0.0	0.1	0.002

	Equivalent Length Temp. Sensors (m)	Equivalent Length Press. Sensors (m)	Pressure Drop Coldplates	Pressure Drop Chk. Valves
Core-Parallel Flow	0.61	0.30	0.04	0.3
Core-Total Flow	0.30	0.00	0.00	0.0
Experiment Rack-1	0.91	0.30	0.012	0.3
Experiment Rack-2	0.91	0.30	0.012	0.3

	Pressure Drop Manual Valves	Pressure Drop L. Sol. Valves	Pressure Drop Bypass Relief V	Velocity (m/s)
Core-Parallel Flow	0	0	0	0.54
Core-Total Flow	10.8	3.17	0	1.62
Experiment Rack-1	0.3	0.09	0	0.27
Experiment Rack-2	0.3	0.09	0	0.27

	Reynolds Number	Friction Factor	Total Equivalent Line Length (m)	Pressure Drop Line Length (kPa)
Core-Parallel Flow	6665	0.035	13.94	9.06
Core-Total Flow	19994	0.027	5.87	26.08
Experiment Rack-1	3332	0.042	9.14	1.77
Experiment Rack-2	3332	0.042	12.50	2.41

Assumptions:

1) All flow in Core Loop-Parallel Flow goes through worst case branch of coldplates.
2) Line is 3/8" O.D., 0.305" I.D.
3) Pressure drop analysis does not consider bypass loop in Core Rack.
4) Rack Configuration for TCS is assumed such that the Core Rack is left of Experiment Rack 1 and ER1 is left of ER2.
5) Pressure Drop for check valves and manual valves is read off vendor data curves.
6) Pressure Drop across pump package is assumed to be one psi.
7) Temperature sensors and pressure transducers are assumed to have pressure drops in the form of equivalent lengths of one foot each.
8) Estimated equivalent line length for each part is multiplied by three to account for fittings.

APPENDIX B
COMPONENT DATA SHEETS

SSFF TCS SPECIFICATION SHEET

Item Name: Heat Exchanger

Component ID #: TCS HX-01

Quantity: 1

Description: The water/water heat exchanger provides the interface between the Space Station Freedom (SSF) internal thermal control loop and a non-standard water thermal control loop within the SSFF payload rack. This is a counterflow configuration heat exchanger constructed of stainless steel with nickel fins.

TYPICAL CHARACTERISTICS

Mass: 13.6 kg (dry)

Volume: 10,573 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: hot-side inlet temperature of 62°C, cold-side inlet temperature of 23.9°C

Pressure Range: 0 to 698.5 kPa

Pressure Drop: 0.035 kg/sq. cm max at design flow

Other: Design flow rate of 499 kg/hr
heat transfer capacity of 8000 Watts

SSFF TCS SPECIFICATION SHEET

Item Name: Pump Package

Component ID #: TCS PP-01

Quantity: 1

Description: The function of the Pump Package is to provide water coolant flow to SSFF subsystem and furnace module components that require heat removal by a secondary coolant loop. The operating fluid is water. The pump package includes two redundant positive displacement gear pumps with bypass relief valves, an accumulator with a quantity sensor, check valves to prevent the fluid from backing into the pumps, one screen on the inlet of each pump, inlet and outlet pressure sensors, and an inlet temperature sensor.

TYPICAL CHARACTERISTICS

Mass: 15.9 kg

Volume: 19,050 cm3

Power Required: 132 Watts

Input Voltage: 115/200 Vac, 3 phase, 400 Hz.

Temperature Range: 23.9°C to 62°C

Pressure Range: 172 - 427 kPa

Pressure Drop: N/A

Other: Flow rate = 272 kg/hr
Accumulator volume = 3392 cm3
Accumulator type = gas charged welded metal bellows
Quantity sensor type = potentiometer
Temperature sensor type = RTD
Pressure sensor type = strain gauge, thin foil
Bypass valve type = spring loaded poppet

SSFF TCS SPECIFICATION SHEET

Item Name:	Flow Meter
Component ID #:	TCS FM-01 through TCS FM-04
Quantity:	4
Description:	The water flow meter measures the cooling water flow rate at the inlet of each coldplate leg in the SSFF core rack and each of the experiment rack legs. The water flow meter provides flow proportioning data to the crew/ground controller.

TYPICAL CHARACTERISTICS

Mass:	0.8 kg each
Volume:	229 cm3 each
Power Required:	1.5 Watts
Input Voltage:	120 Vdc
Temperature Range:	23.9°C to 62°C
Pressure Range:	0 - 689.5 kPa
Pressure Drop:	0.7 kPa at 45 kg/hr
Other:	

SSFF TCS SPECIFICATION SHEET

Item Name: Flow Control Valve

Component ID #: TCS FCV-01 to TCS FCV-04

Quantity: 4

Description: The purpose of the flow control valve is to control the flow of cooling water to the various legs of the SSFF TCS water loop as needed to maintain the correct flow for subsystem and furnace module equipment cooling for new mission sets.

TYPICAL CHARACTERISTICS

Mass: 1.9 kg each

Volume: 2793 cm3

Power Required: 7.0 Watts

Input Voltage: 120 Vdc

Temperature Range: 23.9°C to 62°C

Pressure Range: 0 to 689.5 kPa

Pressure Drop: 1.7 kPa at 558 kg/hr

Other:

SSFF TCS SPECIFICATION SHEET

Item Name: Shutoff Valve

Component ID #: TCS SO-01 to TCS SO-04

Quantity: 4

Description: The purpose of the shutoff valve is to direct flow between two TCS water loop branches. The shutoff valve provides the capability to bypass SSFF experiment racks if the furnace modules are not operating.

TYPICAL CHARACTERISTICS

Mass: 1.9 kg each

Volume: 2793 cm3

Power Required: 7.0 Watts

Input Voltage: 120 Vdc

Temperature Range: 23.9°C to 62°C

Pressure Range: 0 to 689.5 kPa

Pressure Drop: 1.7 kPa at 558 kg/hr

Other:

SSFF TCS SPECIFICATION SHEET

Item Name:	Temperature Sensor
Component ID #:	TCS TS-01 to TCS TS-11
Quantity:	11
Description:	The function of the temperature sensor is to monitor the temperature of the cooling water at various locations in the TCS water loop.

TYPICAL CHARACTERISTICS

Mass:	0.1 kg each
Volume:	45.5 cm3
Power Required:	0.1 Watt
Input Voltage:	120 Vdc
Temperature Range:	23.9°C to 62°C
Pressure Range:	0 - 689.5 kPa
Pressure Drop:	2 kPa
Other:	

SSFF TCS SPECIFICATION SHEET

Item Name:	Pressure Transducer
Component ID #:	TCS PT-01 to TCS PT-05
Quantity:	5
Description:	The function of the pressure transducer is to provide an electric signal which is directly proportional to the pressure of the cooling water in the TCS water loop.

TYPICAL CHARACTERISTICS

Mass:	0.5 kg each
Volume:	168.5 cm3
Power Required:	1.2 Watts
Input Voltage:	28±4 Volts
Temperature Range:	23.9 to 62°C
Pressure Range:	0 to 689.5 kPa
Pressure Drop:	2 kPa
Other:	

SSFF TCS SPECIFICATION SHEET

Item Name:	Coldplate
Component ID #:	TCS CP-01, TCS CP-03, TCS CP-04, TCS CP-07, TCS CP-09, TCS CP-10
Quantity:	6
Description:	The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are custom-built coldplates.

TYPICAL CHARACTERISTICS

Mass:	6.0 kg each
Volume:	1290 cm3
Power Required:	N/A
Input Voltage:	N/A
Temperature Range:	23.9 to 62 °C
Pressure Range:	103 to 621 kPa
Pressure Drop:	4 kPa at max flow rate
Other:	Flow rate 45.4 kg/hr Overall conductance 1.5 w/sq. in. °F (min) Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name: Coldplate

Component ID #: TCS CP-05, TCS CP-06

Quantity: 2

Description: The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are WP-01 -5 coldplates.

TYPICAL CHARACTERISTICS

Mass: 1.6 kg each

Volume: 251.4 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 4 to 49 °C

Pressure Range: 103 to 621 kPa

Pressure Drop: 4 kPa at max flow rate

Other: Flow rate 11-136 kg/hr
Overall conductance 1.5 w/sq. in. °F (min)
Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name: Coldplate

Component ID #: TCS CP-02, TCS CP-08

Quantity: 2

Description: The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are custom coldplates.

TYPICAL CHARACTERISTICS

Mass: 4.9 kg each

Volume: 1104 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 23.9 to 62 °C

Pressure Range: 0 to 689.5 kPa

Pressure Drop: 4 kPa at max flow rate

Other: Flow rate 45.4 kg/hr
Overall conductance 1.5 w/sq. in. °F (min)
Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name: Coldplate

Component ID #: TCS CP-11 to TCS CP-17

Quantity: 7

Description: The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are modified WP-01 -7 coldplates. The -7 is modified so that equipment will mount on the opposite side of the coldplate from the manifold instead of the current configuration in which the item mounts on the same side as the manifold.

TYPICAL CHARACTERISTICS

Mass: 3.9 kg each

Volume: 578.5 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 23.9 to 62 °C

Pressure Range: 0 to 689.5 kPa

Pressure Drop: 7 kPa at max flow rate

Other: Flow rate 11-136 kg/hr
Overall conductance 1.5 w/sq. in. °F (min)
Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name: Quick Disconnect

Component ID #: TCS QD-01 to TCS QD-64

Quantity: 64

Description: The quick disconnect provides a means of manually disconnecting an experiment or subsystem component from the TCS water line. The couplings have self-sealing action.

TYPICAL CHARACTERISTICS

Mass: 0.1 kg each

Volume: 59.4 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 23.9 to 62°C

Pressure Range: 0 to 27580 kPa

Pressure Drop: TBD

Other: Max fluid loss = 0.003 cc
max air inclusion = 0.005 cc

SSFF TCS SPECIFICATION SHEET

Item Name:	Check Valve
Component ID #:	TCS CV-01 to TCS CV-04
Quantity:	4
Description:	The purpose of the check valve is to prevent reverse flow in the TCS water lines.

TYPICAL CHARACTERISTICS

Mass:	0.1 kg each
Volume:	32.5 cm3
Power Required:	N/A
Input Voltage:	N/A
Temperature Range:	23.9 °C to 62 °C
Pressure Range:	0 to 4137 kPa
Pressure Drop:	2 kPa at 45.4 kg/hr
Other:	Minimum cracking pressure = 2 inches water Maximum cracking pressure = 8 inches water Burst pressure = 1500 psia

SSFF TCS SPECIFICATION SHEET

Item Name: Manual Valve

Component ID #: TCS MV-01 to TCS MV-04

Quantity: 4

Description: The function of the manual valve is to control the flow of cooling water in the water loop as needed, in the event of power loss rendering the shutoff valves inoperable and for the launch environment.

TYPICAL CHARACTERISTICS

Mass: 0.1 kg each

Volume: 63 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: -62 °C to 177 °C

Pressure Range: 0 to 15169 kPa

Pressure Drop: 2 kPa at 45.4 kg/hr

Other:

SSFF TCS SPECIFICATION SHEET

Item Name: Accumulator

Component ID #: TCS ACC-01 to TCS ACC-02

Quantity: 2

Description: Accumulators are provided in each experiment rack to compensate for the thermal expansion of cooling water during normal and abnormal (i.e., loss of cooling) operational modes.

TYPICAL CHARACTERISTICS

Mass: 2.7 kg each

Volume: 3791 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: -57 °C to 316 °C

Pressure Range: 0 to 1034 kPa

Pressure Drop: TBD

Other: Proof pressure = 1379 kPa
Burst pressure = 2068 kPa
Expellable volume = 819 cm3

SPACE STATION FURNACE FACILITY MECHANICAL STRUCTURES SUBSYSTEM (SSFF MSS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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C-4

SPACE STATION FURNACE FACILITY MECHANICAL STRUCTURES SUBSYSTEM (SSFF MSS) CONCEPT REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

Prepared By :

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EXECUTIVE SUMMARY

This report will define the Mechanical Structures Subsystem (MSS) that is to be used for integration of the Space Station Furnace Facility (SSFF). The primary functions of the MSS are to support the subsystem hardware and furnace module(s) during launch and landing environments and during operation of the facility while on orbit. These rack structures will allow ease of integration, reconfiguration, or servicing while on the ground or in flight.

The report will address the scope and purpose, groundrules and assumptions, requirements for the facility, design and trades, and detailed description of the core rack and the experiment rack to be utilized for SSFF.

The MSS consists of three rack structures, a core (six post rack) and two experiment racks (modified four post rack). Ancillary structural hardware items which accommodate the various subsystem components and furnace modules within the basic rack frame is also considered part of the MSS. These ancillary MSS items consist of such things as brackets, trays, slides, braces, close-out plates, and the various mounting and structural members which support and align the subsystem hardware with the load paths of the carrier. The racks must meet the requirements of the International Standard Payload Rack (ISPR) for mounting in the modules and for interfacing with the Space Station Freedom (SSF) resources.

The subsystems to be accommodated by the MSS are the Data Management Subsystem, Power Conditioning and Distribution Subsystem, Gas Distribution Subsystem, Thermal Control Subsystem, and the Video Subsystem. The MSS must also accommodate the furnaces outlined in the Science Capability Requirements Document. The standard SSF-to-payload interfaces must be accommodated by the MSS which include the Fire Detection and Suppression for all powered racks and Avionics Air for cooling. The facility will require interrack cabling since the core rack will serve as the service interface to each of the experiment racks. This requirement leads to the design of an interconnect tray that is designed to lay in the standoff area under each of the SSFF racks.

Several trades have been considered such as: 1) the need to provide interrack connection of a large complement of cables and lines, 2) the need to make the system easily reconfigurable for various furnaces and/or furnace configurations, 3) the need to accommodate a large IFEA and facilitate its installation and removal, and 4) on orbit maintenance of the SSFF and component changeout.

Each of the racks are aluminum. The core rack is the six post version of the space station composite rack and is estimated at 84 kg (185 lbs). The experiment racks are a specially modified version of the four post space station composite rack. The ISPR interface panel has been removed from the furnace rack so that the structure can be utilized for all of the furnaces defined in the

Science Capability Requirements Document (furnace height for the CGF could not be accommodated in the standard space station rack). The estimated mass of the experiment rack is 120 kg (263 lbs).

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ABBREVIATIONS AND ACRONYMS

CGF	Crystal Growth Experiment
cm	Centimeter
ESA	European Space Agency
FAU	Furnace Acquisition Unit
FCU	Furnace Control Unit
FSE	Flight Support Equipment
GSE	Ground Support Equipment
kg	Kilogram
IFEA	Integrated Furnace Enclosure Assembly
ISPR	International Standard Payload Rack
lbs	Pounds
MSAD	Materials Science Applications Division
MSS	Mechanical Structures Subsystem
ORU	Orbital Replacement Unit
PMZF	Programmable Multi-Zone Furnace
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBE	Teledyne Brown Engineering
TCS	Thermal Control System
WP	Work Package

1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The purpose of the Space Station Furnace Facility (SSFF) Mechanical Structures Subsystem (MSS) is to support the subsystem hardware during the launch and landing environments and to also make the subsystem items modular and facilitate their integration, reconfiguration, or servicing while on the ground or on board the US Lab Module of Space Station Freedom (SSF). The MSS consists of two fundamental rack type structures, an aluminum core (six post rack) and a furnace rack (modified four post rack), reference Figure 1, along with the minor structural hardware items which are necessary for accommodating the various subsystem components and the experiment within the basic rack frame work. These minor MSS items consist of such things as brackets, trays, slides, braces, close out plates, and the various mounting and structural members which support, align, and react the subsystem hardware load paths. The MSS is only conceptually developed in this study phase and would have to be thoroughly analyzed in the subsequent Phase C/D to insure all applicable stress, fracture, and fatigue requirements for SSF are met.

The major part of this study effort has been directed toward the development of a considerable depth of definition of the rack frame structures to be employed by the SSFF. This report will detail the extent of that data base. Other elements of the concept are developed to a lesser degree, but are presented in a conceptual nature. One such item which is only presented pictorially in this report is an interconnecting tray structure which is also an integral part of the SSFF/MSS concept. The concept is shown in Figure 2 and was conceptually verified by TBE in a mock up in the Interrack Demonstration Unit. The exact details of how this tray will be manifested for delivery to SSF has not been determined. It is expected that a special piece of MPE/FSE will be required for transport of the tray to orbit.

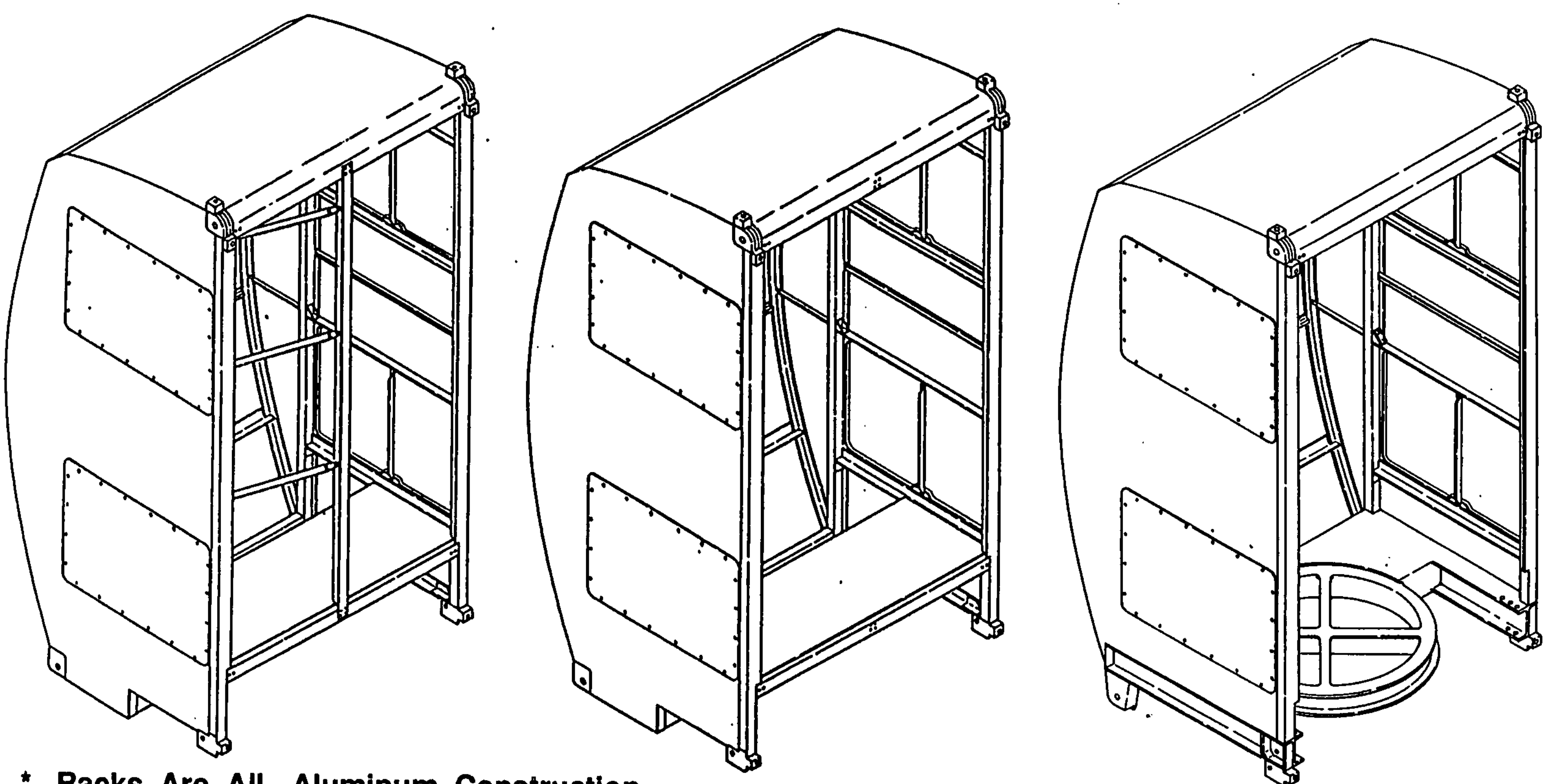
Other elements of the complete MSS complement for SSFF (like the tray) are also not fully developed due to the lack of a complete understanding of the the proposed SSF payload integration process and the FSE/GSE which will (or will not) be available from the SSF program for use by the SSFF development contractor. A basic ground rule employed in development of the SSFF MSS, however, is that the SSFF equipment must be compatible with all the SSF program rack GSE, including such things as slings, work stands, shipping containers, and installation and handling equipment.

1.2 GROUNDRULES AND ASSUMPTIONS

The following ground rules and assumptions have been made in the conceptual development of the SSFF/MSS as described herein:

THREE TYPES OF RACKS AVAILABLE :

- TYPE I, Six Post	- TYPE II, Four Post	TYPE III, Mod 4 Post
SSFF Core Rack	For Small Furnaces	Large Furnaces (CGF)



* **Racks Are All - Aluminum Construction**

FIGURE 1. RACK STRUCTURAL CONFIGURATIONS

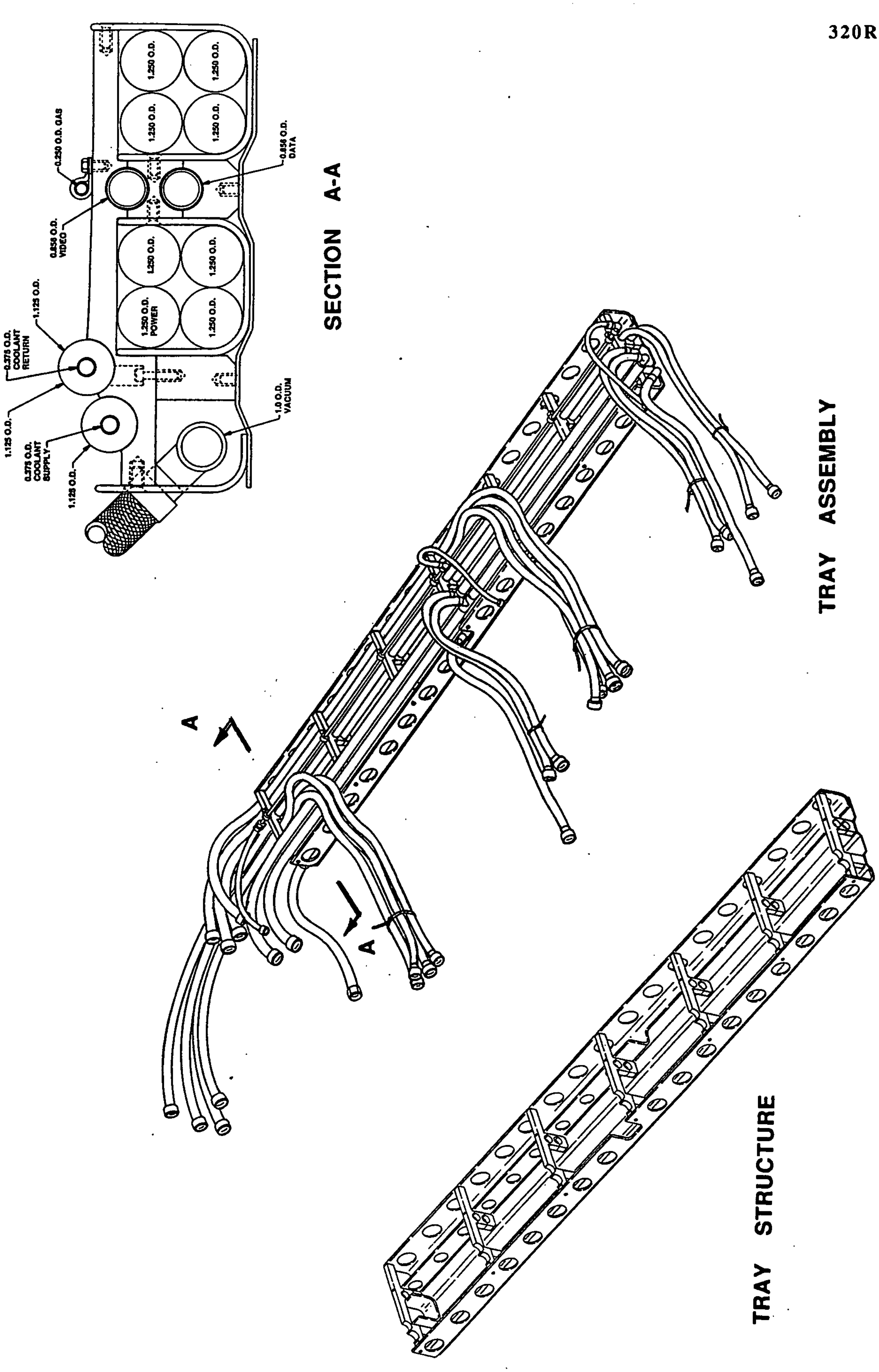


FIGURE 2. SSFF INTERCONNECT TRAY

- The SSFF will comprise a three double rack facility in the Space Station Freedom Lab A Module. The facility packaging is to be compatible with the International Standard Payload Rack (ISPR) requirements given in SSP41002. Compliance with the ISPR standards will not preclude the possible use of the facility in the ESA or NASDA Modules, nor shall manifesting of the facility with only one experiment module degrade its full operational capability.

- For initial facility deployment it has been assumed that the core rack and only one experiment module will be fielded. An additional one half rack space is required, however, for the transport of the facility interconnect tray to orbit. In addition, it is assumed that there will be on orbit storage space for facility supplies, spares/ORU's, and tools in the equivalent of another half rack volume. Until such time as all three double rack spaces are fully operational, the third rack position could be designated as a temporary equipment transport/storage rack for the purpose of tray delivery and on orbit storage. When the program fields the second experiment module, this rack would have to be returned or moved to a different LAB location where SSFF would still require one half its volume for storage. The Module 1 study has also raised some issues relative to additional rack service space that need to be considered in the over all SSFF utilization planning for SSF.

- The two furnace IFEA configurations to be utilized for development of the furnace rack design and integrated equipment arrangements are assumed to be the CGF and PMZF, both of which are assumed to fit within the same IFEA profile, 66 cm (26 inch) diameter by 165 cm (65 inch) long and are expected to weigh less than 350 kg (770 lbs).

- The MSS design has assumed that obtaining custom cold plates for specific facility needs will not be a programmatic problem. The packaging flexibility is severely restricted if the facility selection is limited to the WP1 plates.

- A common quick release clamp type base plate interface is to be provided as the furnace to rack interface for all furnaces. This interface is to be modeled on a 66 cm (26 in) diameter base ring for CGF/PMZF which will be adaptable to other future designs with smaller diameters.

- The rack structures and outfitting are to be compatible with SSF ISPR services interfaces, such as the gas, fluid, and electronic operational/supply systems. The subsystem modular arrangements and packaging shall also meet the program logistic and resupply packaging requirements, and other SSF program maintenance requirements. The designs are not to preclude the use of other SSF developed integration, support, and test equipment.

2. REQUIREMENTS

2.1 GENERAL

The SSFF MSS shall meet the requirements identified in 320SPC0001, Contract End Item Specification, Part 1, for Space Station Furnace Facility. In addition the MSS is to accommodate the physical mounting requirements of the subsystems and experiment equipment as development or implied by the Science Capabilities Requirements Document. A separate specification has been prepared for the SSFF racks. The rack structural elements of the MSS would also have to comply with the requirements detailed in that document.

2.2 INTERFACE REQUIREMENTS

2.2.1 MSS Interfaces to SSFF

The SSFF/MSS will provide the physical interfaces between the subsystem and experiment equipment in the three double racks and react their operational loads to the six different SSF physical attachment points provided at each rack location. There are two main structural interfaces on the lower rear corners of each rack which react the major portions of the launch and recovery loads, one is fixed in all three axes and the other is fixed in two axes but released in the "X" (LAB Module longitudinal) direction. Two other attachments at the front upper corners interface with strut assemblies which carry lateral loads (these points float vertically) back to the wall of the SSF module. These four primary load interfaces are releasable on orbit to permit individual rack relocation and/or rotation for access to the module wall. The rear attachments are released permanently while on orbit and a special pivot fitting on the lower front corners of the racks is deployable by the astronauts for use as the main rack lower support in the weightless environment on orbit. For launch there are two upper rack attach points active, while on orbit one will be permanently released.

The interconnect tray assembly is designed to lay in the standoff area under the three SSFF racks and to be secured in place by a method which does not require any modifications to the SSF structure. It is believed that some form of clamp attachment can be employed for this purpose; however, there was not sufficient documentation available on the standoff design in order to complete a conceptual layout for the details of that attachment. As was mentioned in the Introduction to this report , there is also a requirement for some form of FSE to interface the tray assembly to a rack in the Logistics Module for launch (and landing). A conceptual design for this fixture may be available for the MSS final report.

2.2.2 MSS to Subsystem Equipment

The subsystem equipment described in the other sections of this report comprise a diverse collection of components which must be packaged in the facility rack structures. As can be noted

on the various system schematics, the major operational portion of each of the subsystem hardware is located in the core rack. An equally important subset is also required in each furnace rack. This equipment is necessary to satisfy all the safety and system performance requirements, as well as, facilitate the furnace reconfiguration. This concept is what has been referred to as the centralized and distributed equipment sets in the subsystem concepts. Each subsystem concept report includes pertinent data on the components used in the subsystem packaging analysis. The MSS has been tailored to meet these component's packaging and mounting requirements. In general the approach has been to try and group like subsystem elements into modules which are accessible for maintenance or change out. This has resulted in the basic rack arrangement shown in Figures 3 and 4. The MSS interfaces to the subsystem components is therefore at a bolted interface either directly with the component or in the case of a collection of components, with the subcarrier frame work holding the components. It will also be an MSS function to support all the fluid and electronic lines running between subsystem elements. The details of specific MSS features for this purpose has been left till the mock up is completed and a direct visualization of the best line placement and routing can be made.

2.2.3 MSS to Experiment Equipment (Furnaces)

The interface of the MSS with the experiment rack furnace has been specifically developed for SSFF to accommodate an advanced furnace based on a modified CGF type IFEA. The base plate structure used on Space Lab has been replaced with a clamp type universal ring on SSFF as shown conceptually in Figure 5. This change was made because of several considerations under study which indicate that it is not only desirable but also highly likely that the IFEA's will need to be changed out or removed from the racks on orbit. To accomplish such a task with the Space Lab type bolted base would involve removing 12 large fasteners, some of which would be almost inaccessible in an integrated condition. The other interfaces to the furnace to be considered in design of the MSS are the service connections, including those for installation and removal of samples. On CGF all the connection points are located in a ring at the bottom of the IFEA. These lines come out at a number of separate locations around the periphery of the ring as shown in Figure 5. Some options for relocation of these connect points are being studied in an effort to simplify the installation/removal of an IFEA. A new interface for glove box attachment is also being looked at in the Module 1 design task. There has not been time to incorporate any MSS updates due to these optional study efforts; therefore, only the conventional CGF type interfaces will be discussed herein.

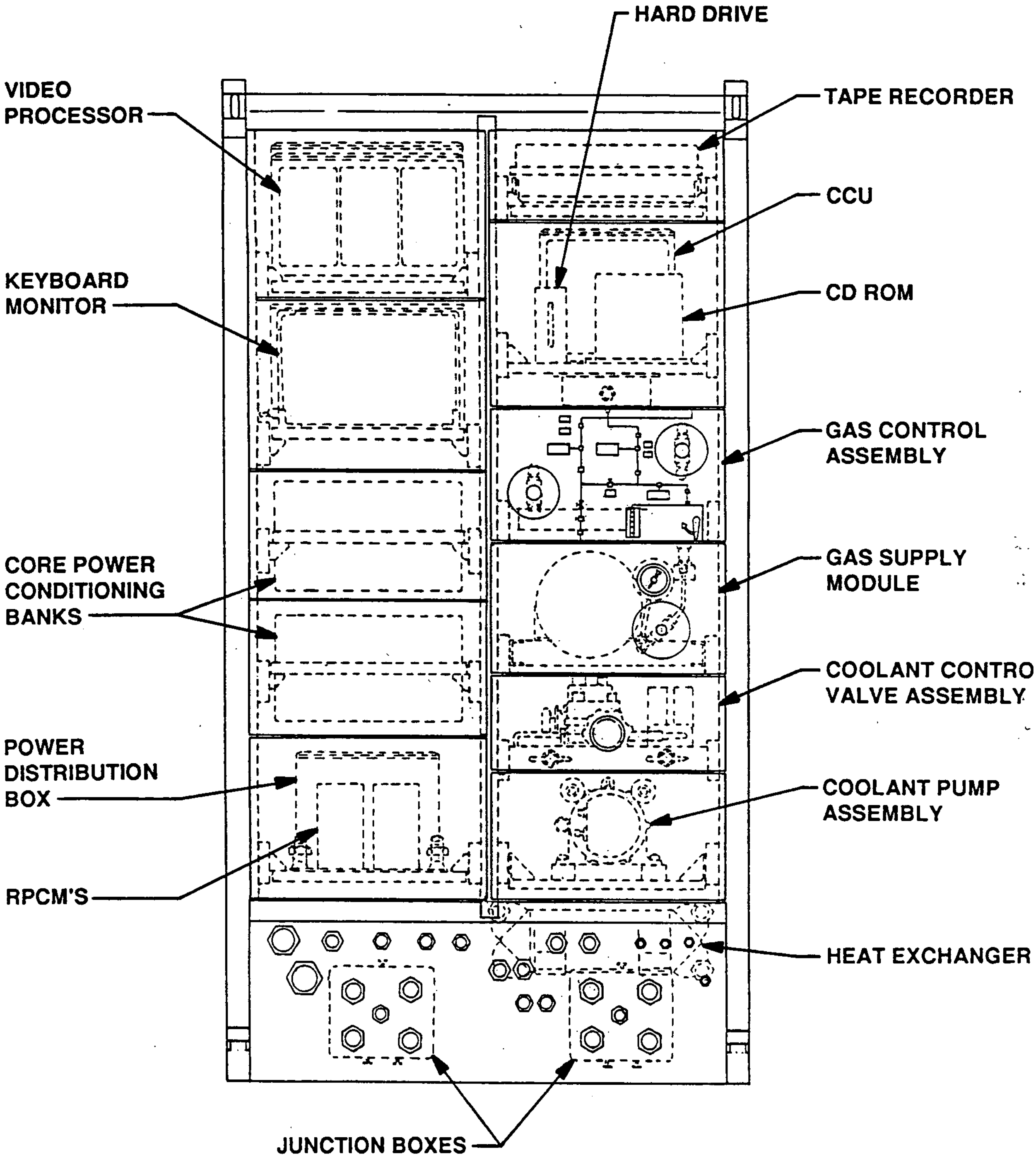


FIGURE 3. SSFF CORE RACK ARRANGEMENT

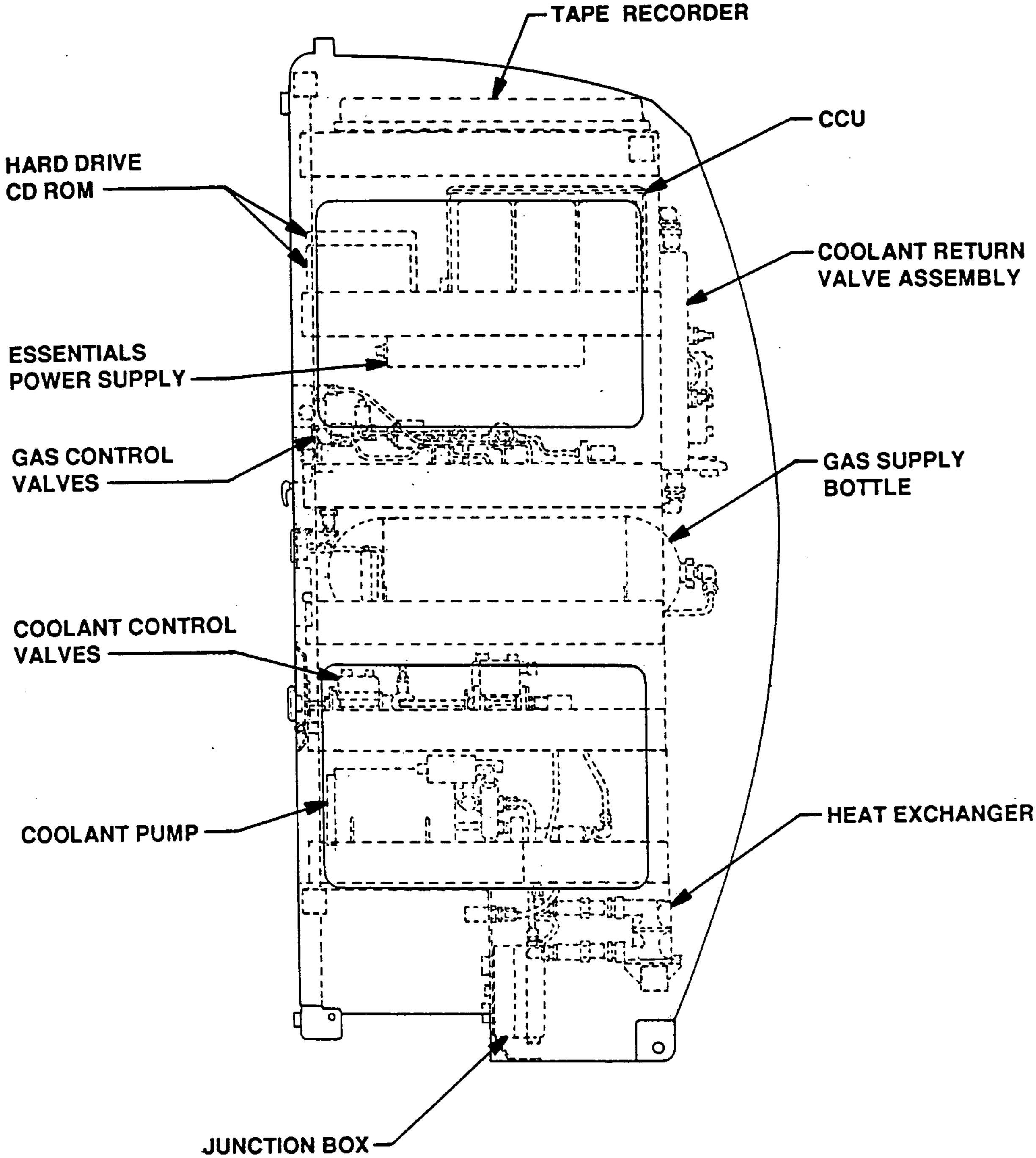


FIGURE 4. SSFF CORE RACK VIEW A - A (Sheet 1 of 2)

Figure 5

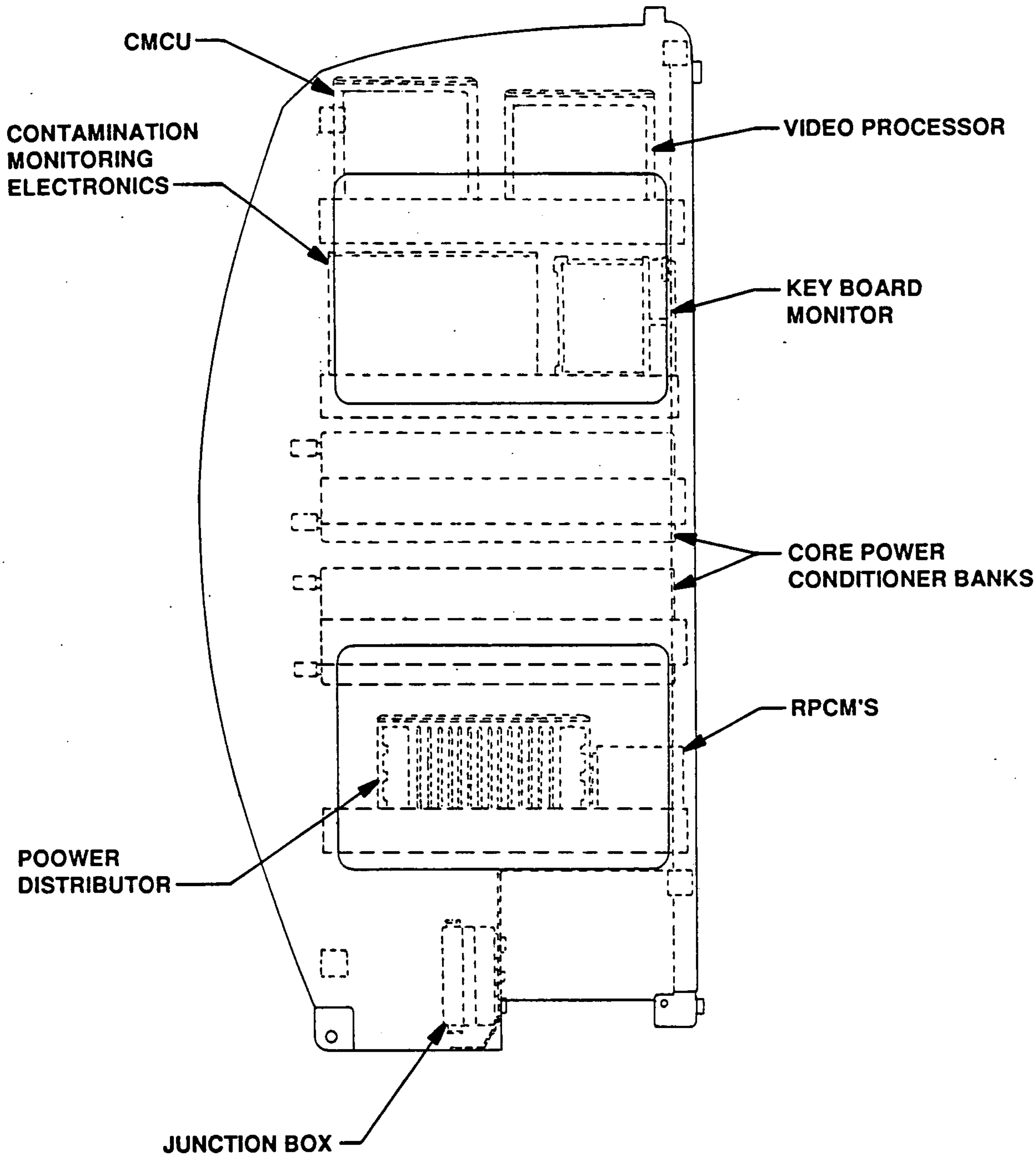


FIGURE 4. SSFF CORE RACK VIEW B - B (Sheet 2 of 2)

Figure 5

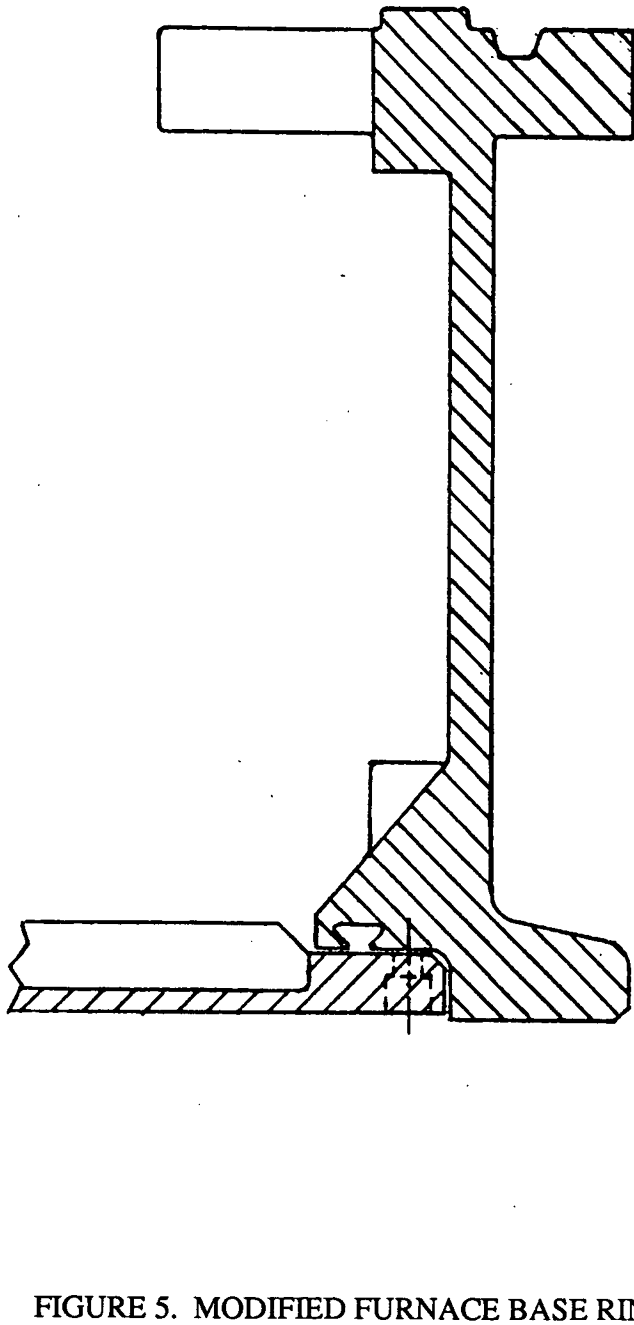


FIGURE 5. MODIFIED FURNACE BASE RING

3.0 CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

At the beginning of the SSFF MSS concept development the major drivers on the system emerged as: 1) the need to provide interrack connection of a large complement of cables and lines, 2) the need to make the system easily reconfigurable for a large number of possible furnace configurations, and 3) the need to accommodate a large IFEA and facilitate its installation and removal. These three areas will be discussed to reveal the trades which were made to arrive at the MSS concept presented.

3.1.1 Interconnect Design

The rack interconnect problem is the subject of a whole separate study task; however, the rack design and the MSS integration hardware are directly driven by the solution to that problem. A study of the furnace service requirements also drove out the trades which determined what equipment eventually was designated to be centralized (located in the core) and that which was necessary to be distributed (located in the furnace rack). The limitation on available space for interconnects was a prime driver on those decisions. Relatively early in the SSFF interconnect study it became obvious that the interconnect lines needed to pass through a notch in the bottom front corner of the core rack and to traverse a similar clear passage under the adjacent furnace racks. To provide this notch would mean that a composite racks would have to have a significant portion of their structure removed and reworked in these corners in order to accommodate the notch. It was felt that this was not an impossible thing to do, but certainly a very difficult task due to the nature of composite construction. The layouts were made for such a feature in the composite rack and the details of the interconnect were carried forward. Factors came forward later in considering the furnace rack design which would cause the design study to seriously consider an alternate rack which lends itself more readily to alteration (specifically to accommodate a large IFEA) and was amenable to rapid reconfiguration by the user. Figure 6 shows an approach which was developed for integration of CGF in a composite type rack. In reviewing this concept it was felt that extensive reinforcement was being required of the composite rack in order to carry the IFEA loads. This reinforcement was having to pass the load reactions to the rack then to the SSF attachments. It was felt a better approach would be to pass the loads directly to the SSF attachments if possible. Those thoughts are discussed further in Section 3.1.3 below.

3.1.2 SSFF Reconfiguration

The requirement to have a facility which is modular and easily reconfigurable drove the packaging of the subsystem hardware to be grouped by subsystem unique elements and to be installed in easily removable trays or plate mounted units. The options traded in the MSS design

Figure 6

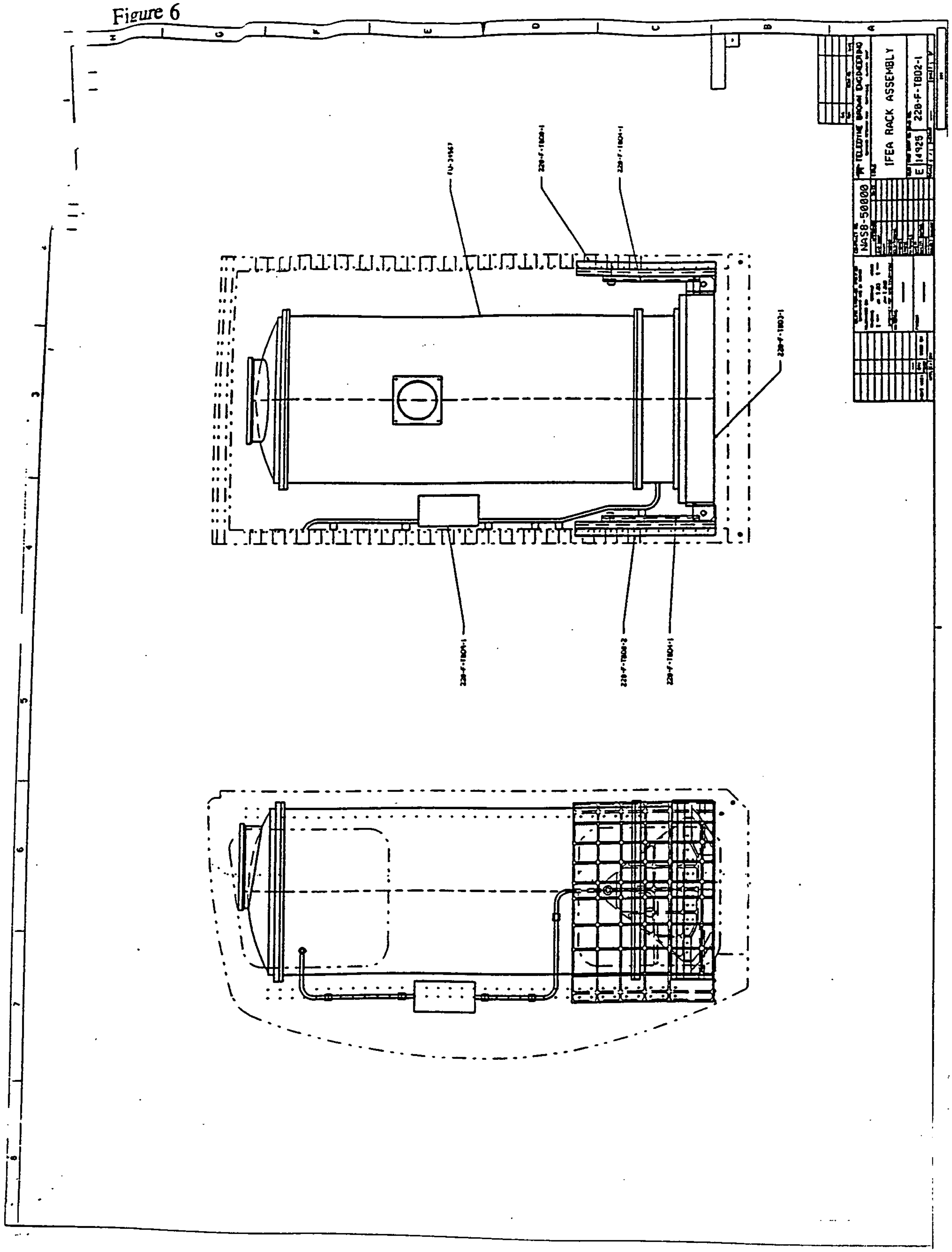


FIGURE 6. CONCEPT OF CGF IN WP1 RACK

dealt primarily with the hardware by which these units could be physically mounted. Options for grouping of subsystem elements were primarily driven by the available space in a single rack tray envelope, by the constraints of achieving an effective discrete functional element, and by considerations of orbital replacement and the ease of maintenance. (A separate study task gives a complete report on the ORU considerations.) Figure 3 shows the basic elements of the MSS employed in the core rack. The subsystem packaging in the furnace rack is a much more difficult problem because of the irregular spaces available for equipment mounting. Figure 7 shows an auxiliary equipment frame which was designed for addition to the back of the basic furnace rack structure to provide a suitable mounting interface for the main electronics boxes. Figure 8 shows how thermal control components have been assembled into frames which can be attached to the rear corner posts. Other elements of the MSS in the furnace racks has been developed conceptually on an individual component by component basis. The completely outfitted furnace rack is shown in Figure 9.

3.1.3 IFEA Installation/Removal

Looking at options for accomplishing the furnace installation which would also allow its relatively rapid removal, it was felt a mission specific rack structure would be better suited than an adaptation to the composite rack. The concept shown in Figure 6 reflects the initial thinking for that approach. The final SSFF rack selection that is being offered in this report was actually developed from a trade analysis performed under a Technical Directive of the MPS Contract, NAS8-38079. In that analysis the pros and cons of an aluminum payload rack were weighed against the composite rack being developed by Work Package 1. An extensive design package for a six post core type rack was subsequently developed on the impetus of these study findings and preliminary analyses showed it was a promising alternate to the WP1 structures. Based on the "good feel" this rack concept gave, it was decided to alter the furnace rack approach of Figure 6, to incorporate the upper rack details from the MPS study. Figure 9 is the resultant furnace rack configuration which TBE is recommending for the SSFF. The core rack TBE recommends is the aluminum rack developed by the MPS study.

3.2 MSS DETAILED DESCRIPTION

3.2.1 Core Rack

The core rack is an aluminum six post version of the space station composite racks. It has four outer corner posts which are special aluminum extruded tubes with a pattern of pre-drilled holes in two flanges at ninety degrees to one another, reference Figure 10. The mission specific MSS is intended to attach to these post hole patterns. If it were necessary to remove the equipment mounted to these flanges on orbit, then a segment of track would be installed behind the flange

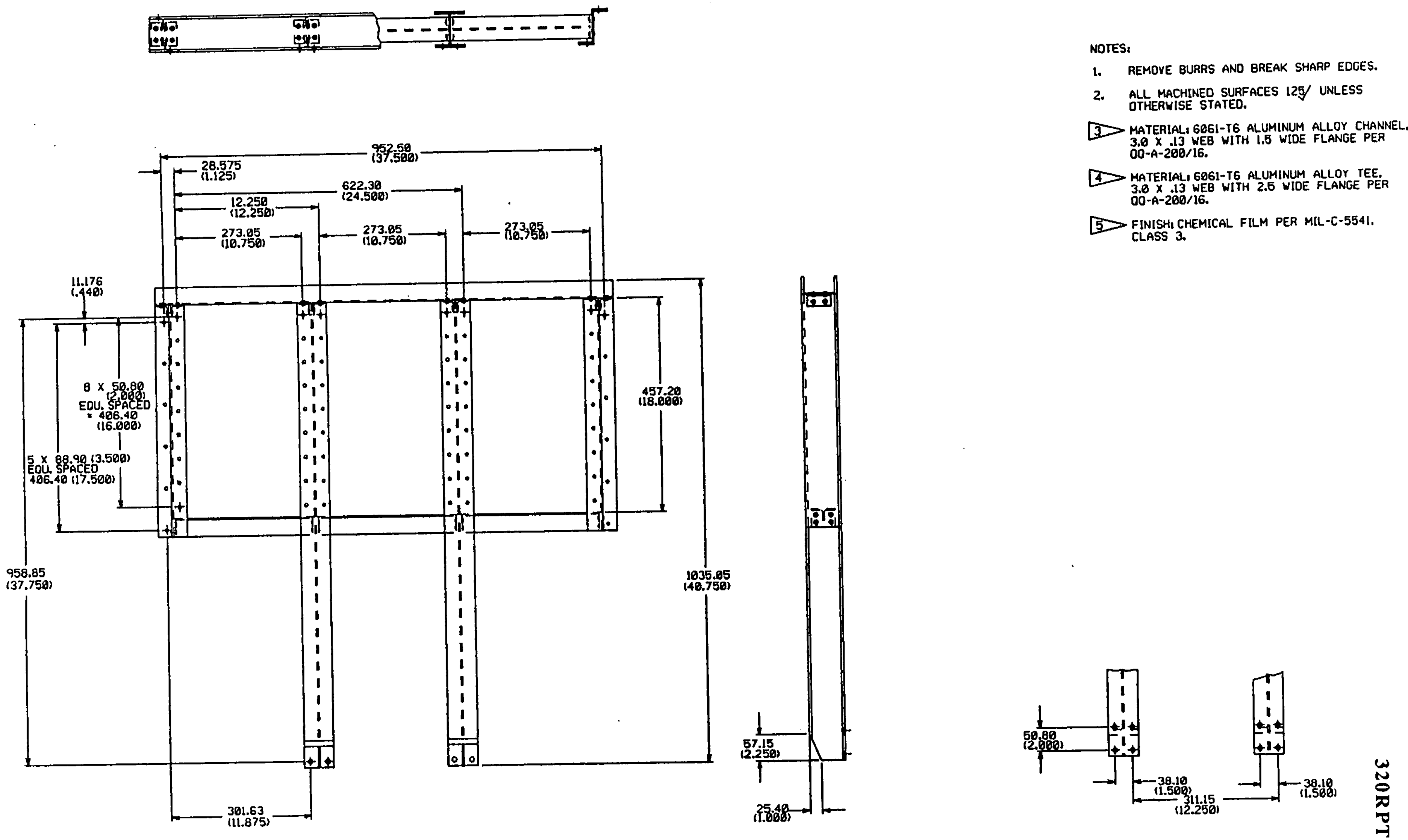
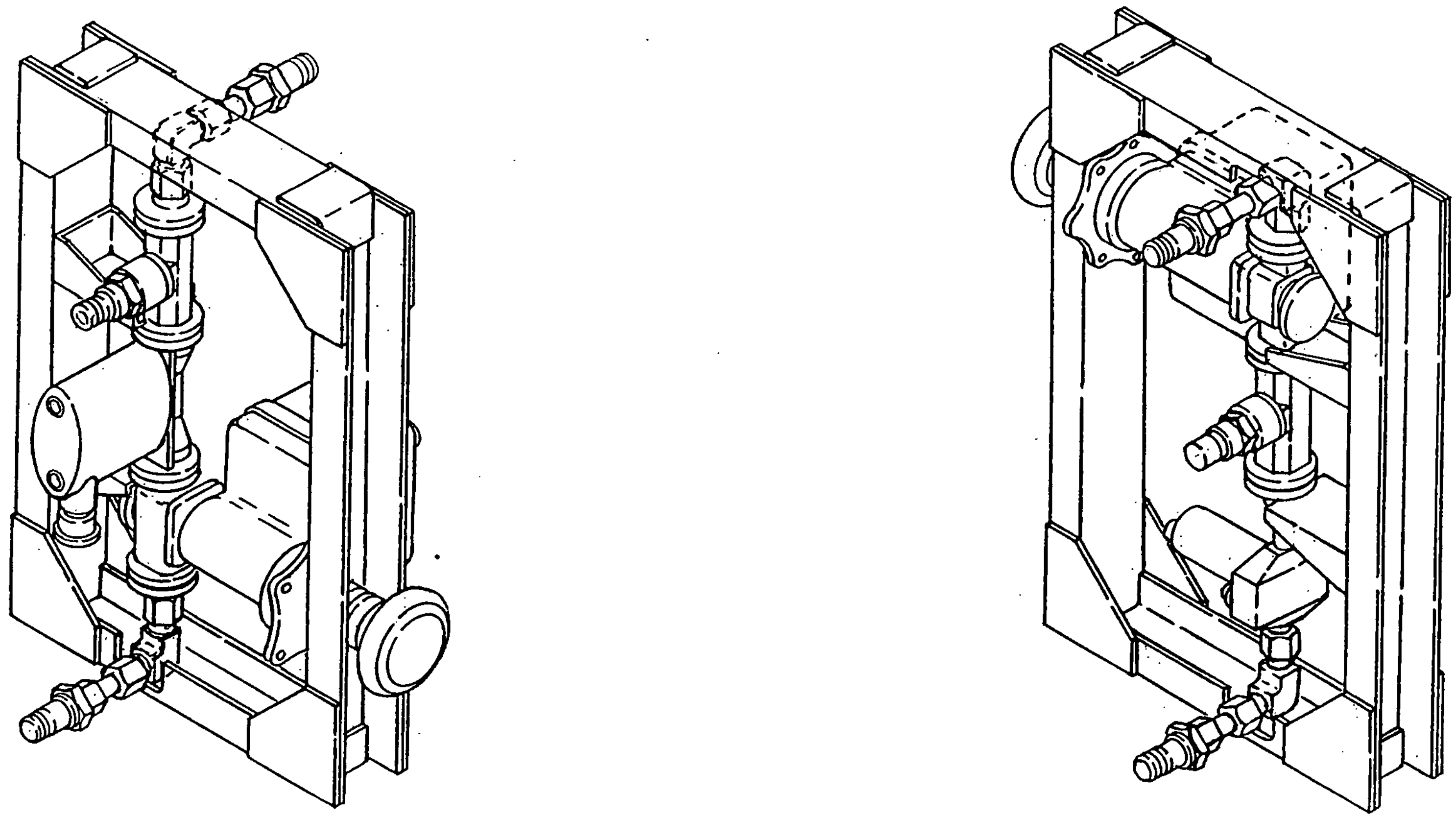


FIGURE 7. EQUIPMENT SUPPORT FRAME



FURNACE COOLANT INLET
CONTROL ASSEMBLY

FURNACE COOLANT RETURN
CONTROL ASSEMBLY

FIGURE 8. FURNACE RACK TCS COMPONENTS

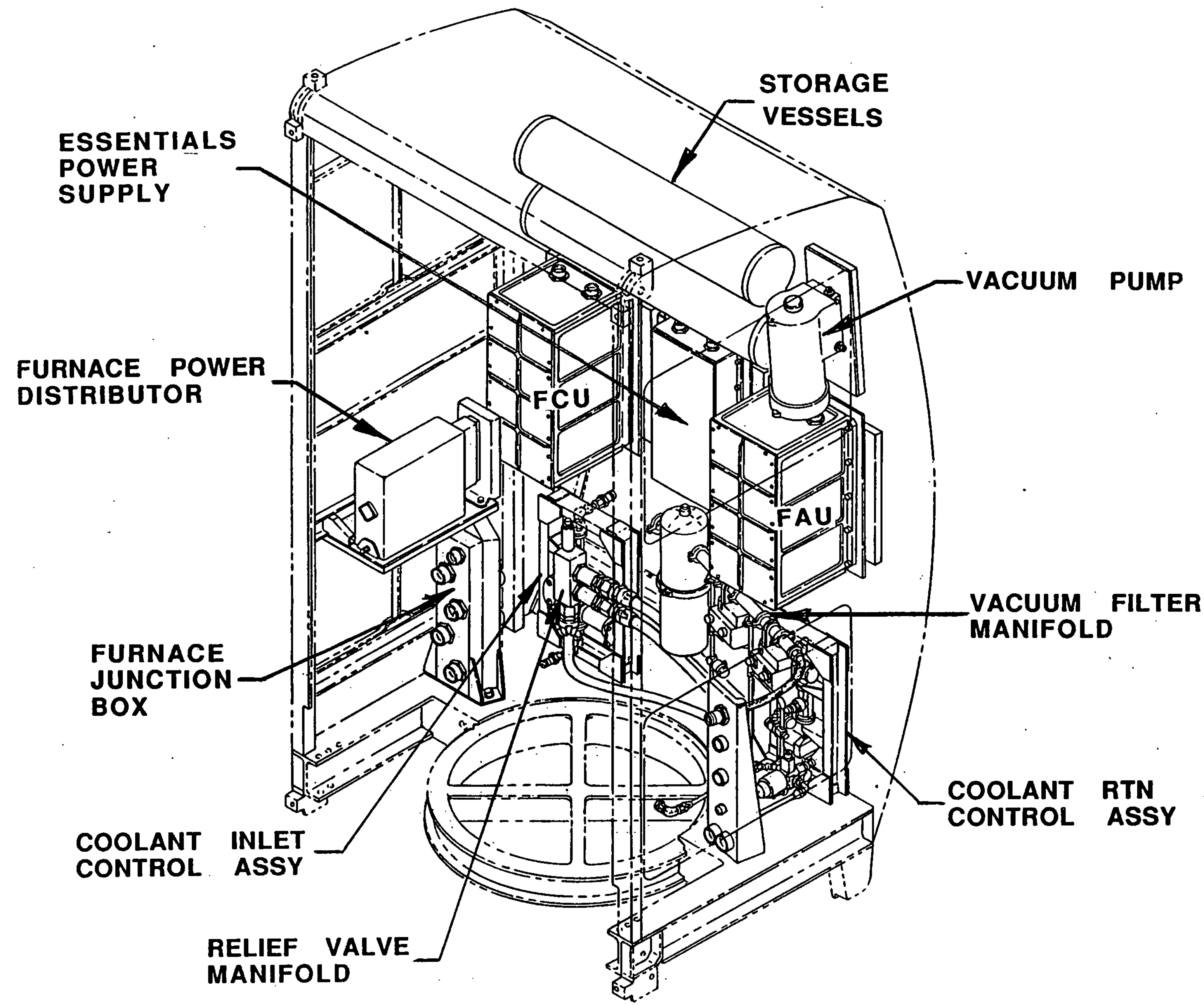


FIGURE 9. FURNACE RACK OUTFITTING

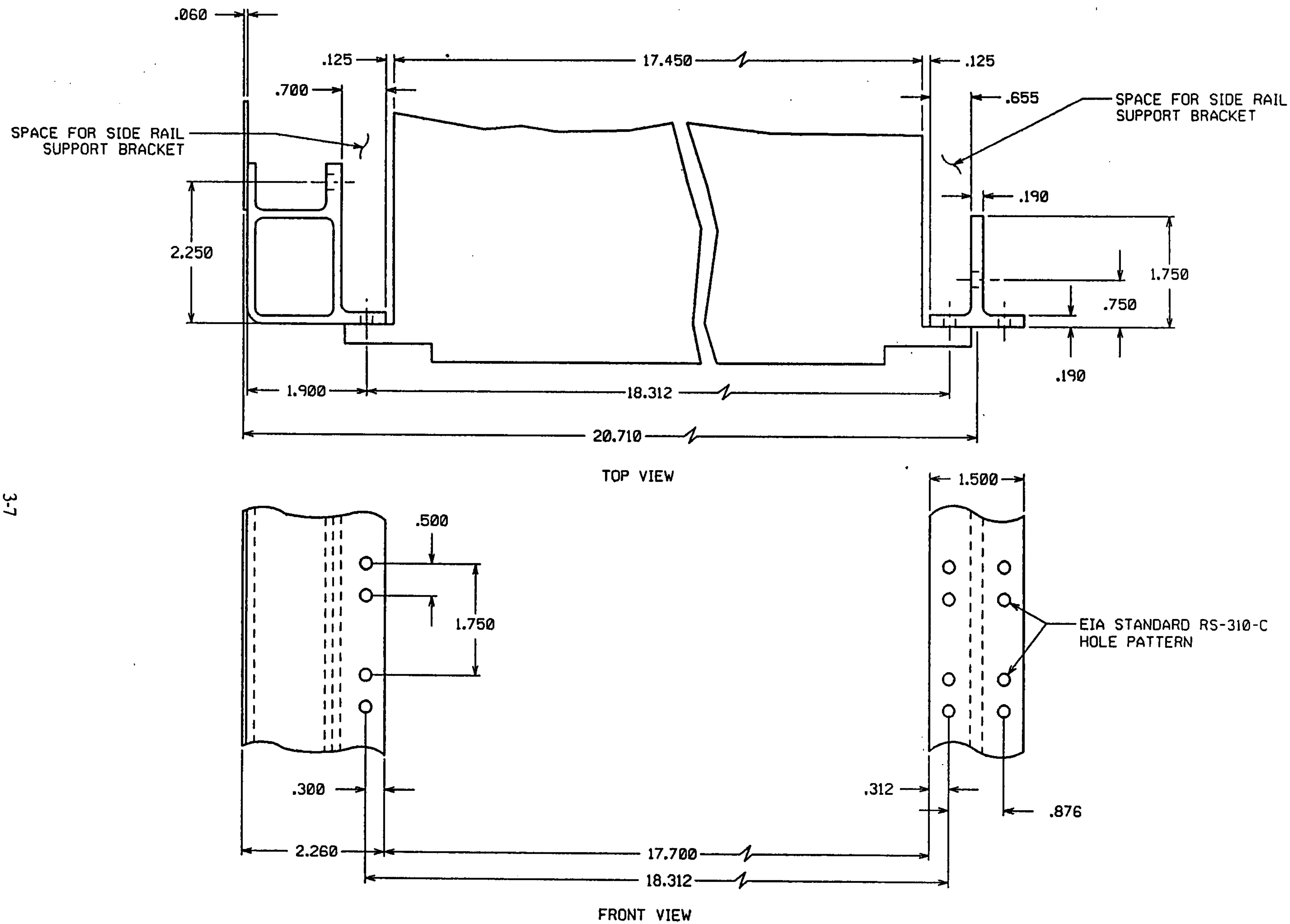


FIGURE 10. SSFF CORE RACK CORNER & CENTER POST DESIGN

which would permit the use of an adjustable blind nut plate assembly for the attachment of subsystem mounting structure. The approach to be utilized in mounting the majority of the SSFF hardware will not need tracks. Most elements of the SSFF MSS will be permanently installed with a regular bolt and lock nut system. Nut plate clips will be employed on the front rack flanges for the individual tray or module face plate closeouts, reference Figure 11.

The core rack is divided into the two bays by a pair of center posts, which are extruded tees. The center post has the same hole patterns on its web and flanges as the outer corner posts, reference Figure 10. The MSS subsystem equipment will utilize the hole patterns in these posts for mounting slide attachment brackets and slide assemblies, Figure 12, which are then interfaced to the modular subsystem assemblies. The slides would always remain installed even if one of the functional subassemblies had to be changed out or reconfigured, see Figure 13. The subsystem equipment is packaged either on an aluminum plate or in a frame work which is attached directly or by brackets to the slides. Some equipment may require additional localized rack mounting holes or brackets which are located by the installation drawings. Because the racks are constructed of aluminum shapes the inclusion of these additional mounting features can be easily accommodated without major impact to the integrity of the structure. Analysis of the specific MSS components and attachment features of the entire rack would be a standard requirement for all integrated configurations.

The drawings developed under the MPS study task for the six post core rack configuration are listed in Table 1. Since that package was generated, it has been decided that some modifications to the rear frame work of the rack are in order for best use as a six post double bay rack. Those modifications would include the addition of a central divider frame which would split the rear access panel into at least two panels approximately 50.8 cm x 101.6 cm (20 in x 40 in). The ORU assessment indicated that there would be many access requirements which did not necessitate access to both bays of the rack interior; therefore, some amount of astronaut time would be saved by having to remove only half the previous panel. Future study may show additional maintenance time savings could be realized by further division into four panels. Handling/storage of a smaller panel is also simpler. A weight estimate for the six post core rack is shown in Table 2.

In addition to the basic rack frame, the MSS in the core rack consists primarily of the tray support plates and slides shown in Figure 12. The plates are envisioned to be milled out of 2.54-3.81 cm (1.0-1.5 in) thick aluminum stock in an isogrid pattern with a flat upper surface and fastener insert node points on 6.985 cm (2.75 in) centers. The fastener nodes match the mounting pattern to be furnished on the SSFF cold plates.

(TBD)

FIGURE 11. RACK FACE PLATE CLOSEOUT

Figure 12

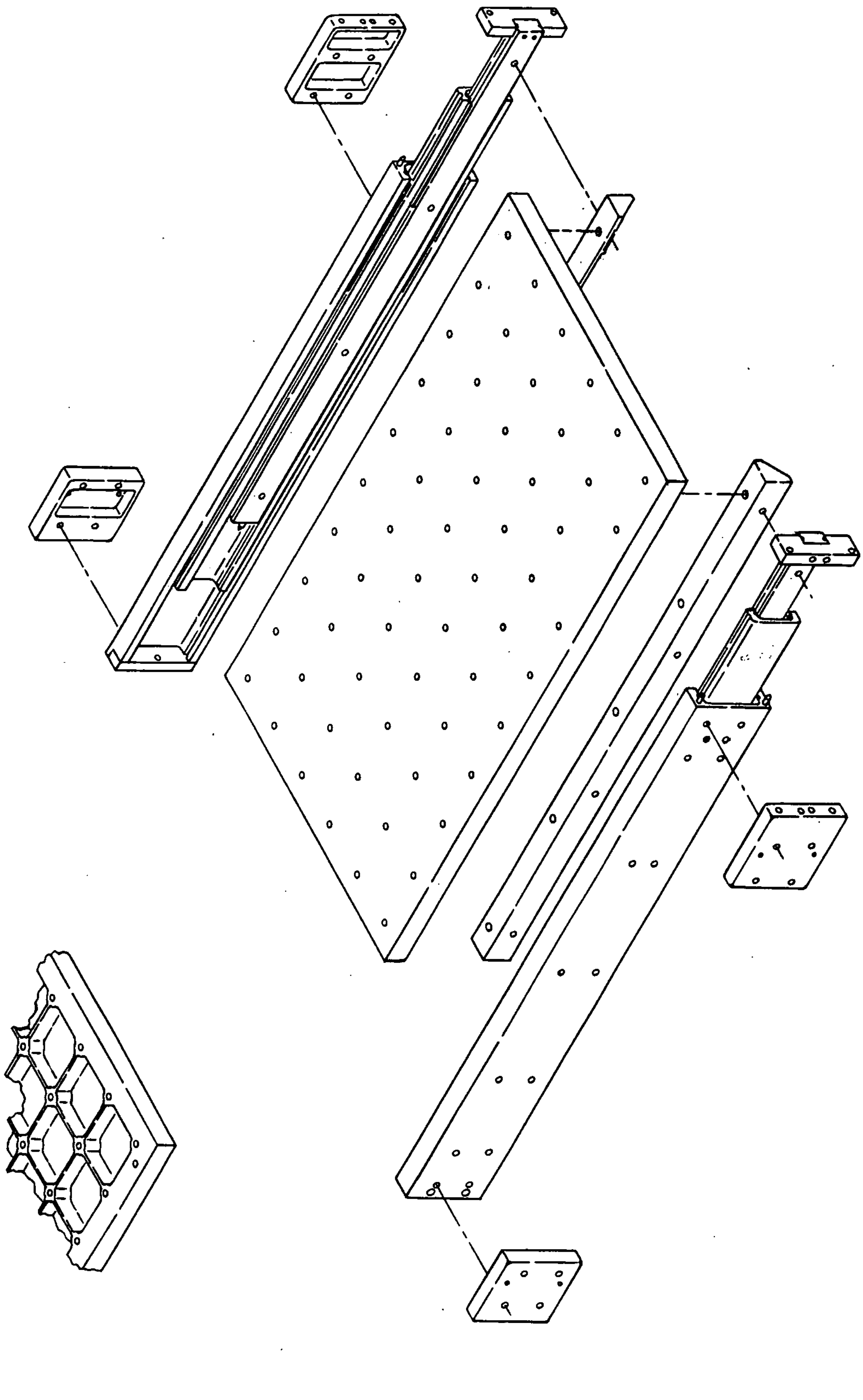


FIGURE 12. TYPICAL EQUIPMENT TRAY ASSEMBLY

(TBD)

FIGURE 13. TYPICAL ORU CHANGE OUT

TABLE 1. SPACE STATION FURNACE FACILITY
ALUMINUM CORE RACK DRAWING TREE

DRAWING TITLE	DRAWING NO.
Payload rack, Level 1 Assembly	JO-18000
Side Access Panel Assembly	JO-18010
Skin Stiffener	JO-18014-01
Rear Access Panel Assembly	JO-18020
Rear Panel Skin Detail	JO-18022
Skin Stiffener	JO-18014-02
ISPR Pass Thru Panel	JO-18030
Upper Attach Mechanism-Assy	683-14036
Pivot Mechanism Details	683-14037
Corner Post Extrusion	JO-18112
Center Post Extrusion	JO-18122
Horizontal tube	JO-18130
Tube End Fitting	JO-18132
Upper Attach Fitting	JO-18140
Lower Attach Fitting	JO-18150
Pivot Housing	JO-18160
Diagonal Brace Assembly	JO-18170
Back Upper Corner Bracket	JO-18190
Skin Support Angles	JO-18200
Fabricated Clips	JO-18210
Skin Stiffeners	JO-18014
Shield Panel	JO-18220
Cargo Track	683-14067

* Only those drawings which were completed are listed. Additional drawings in the tree are shown in the weight estimate given in Table 2.

TABLE 2. SPACE STATION FURNACE FACILITY
ALUMINUM CORE RACK WEIGHT ESTIMATE

Component		Weight Est kg	(lbs)
Front Corner Posts (JO-18110), 2 ea		7.620	(16.760)
Rear Corner Post (JO-18115), 2 ea		7.910	(17.410)
Center Post, Front (JO-18120)		1.630	(3.580)
Center Post, Rear (JO-18125)		1.690	(3.720)
Center Post Clips (JO-18126), 8 ea		0.174	(0.384)
Horizontal Tube (JO-18130), 4 ea		6.400	(14.080)
Tube End Fittings (JO-18132), 8 ea		0.753	(1.656)
Upper Attach Fitting (JO-18140), 2 ea		1.980	(4.356)
Lower Attach Fitting (JO-18150), 2 ea		1.069	(2.352)
Pivot Housing (JO-18160), 2 ea		0.636	(1.400)
Diagonal Brace Assy (JO-18170), 3 ea		1.047	(2.304)
Access Panel Frame Details (JO-18180) Angles		2.484	(5.464)
Straps		0.167	(0.368)
Clips		0.233	(0.512)
Back, Upper Corner Bracket (JO-18190), 2 ea		0.113	(0.248)
Skin Support Angles (JO-18200)	-01	0.132	(0.290)
	-02	0.171	(0.376)
	-03	1.114	(2.450)
	-04	1.936	(4.260)
	-05	1.354	(2.980)
	-06	0.836	(1.840)
Fabricated Clips (JO-18210)		0.319	(0.701)
Skin Stiffeners (JO-18014)		1.365	(3.004)
Shield Panel (JO-18220)		1.947	(4.284)
Close Out Details (JO-18230)		0.909	(2.000)
Cargo Track (683-14067), 2ea		1.571	(3.456)
Side Access Panel Assy (JO-18010), 4ea		5.862	(12.896)
Rear Access Panel Assy (JO-18020)		5.268	(11.590)
ISPR Pass Thru Panel (JO-18030)		1.373	(3.020)
Top Skin (JO-18040)		5.432	(11.950)
Bottom Skin (JO-18050)		3.282	(7.221)
Left Side Skin (JO-18060)		3.982	(8.760)
Right Side Skin (JO-18070)		3.982	(8.760)
Upper Attach Mechanisms (JO-18080)		0.204	(0.450)
Pivot Fitting Assy (JO-18090)		0.174	(0.384)
Fastener Allowance		1.364	(3.000)
Design Margin (10%)		7.658	(16.848)
Rack Total Estimate		84.141	(185.114)

3.2.2 Furnace Rack

The furnace rack is a specially modified version of a four post aluminum core rack. The ISPR interface panel has been removed from the furnace rack so that the lower 203 cm (eight inches) of the structure can be replaced by a one piece machined furnace support structure, Figure 14. This structure carries the vertical loads of the furnace out to the two lower rear SSF attach fittings. A clamp type interface is to be employed in the furnace base ring to mate with this structure. The furnace would set on the front edge of the support and slid horizontally to engage the mating notch milled in the back half of the support platform. A separate bolt on clamp (Figure 15) would close off the front half of this ring and capture the furnace base. Two short beam segments (Figure 16) are installed from the clamp ring to the front corner posts to stiffen the furnace support vertically. A pair of strut assemblies (Figure 17) would also be installed at the top ring of the IFEA to react fore and aft rocking loads/motion of the furnace enclosure and thereby stiffen the lower attachment ring vertically. A dynamics model of the furnace rack arrangement has shown that these elements are necessary to meet the minimum frequency requirement of 25 Hertz for the rack. This same base ring would be a standard interface for other large furnaces. Smaller IFEA modules (say less than 45.7 cm [18 inches] in diameter) could possibly use a four post core type rack with a different type internal support frame work.

The drawings which have been generated in this study for the modified furnace rack structure are listed in Table 3. A major portion of the structural details listed in Table 1 for the core rack also have direct application in the furnace rack. The major additional MSS feature in the furnace rack for subsystem equipment support is a bolt together frame which fastens to the base support and the rear corner posts in back of the IFEA. This frame is shown in Figure 7. The FCU, FAU, and Essentials Power Supply are mounted to plates fastened to the central part of this frame. Some other subsystem elements are also fastened to the legs of the frame below the electronics boxes by component specific brackets. Similar component specific brackets are also used through out the rest of the rack to mount the balance of the subsystem equipment.

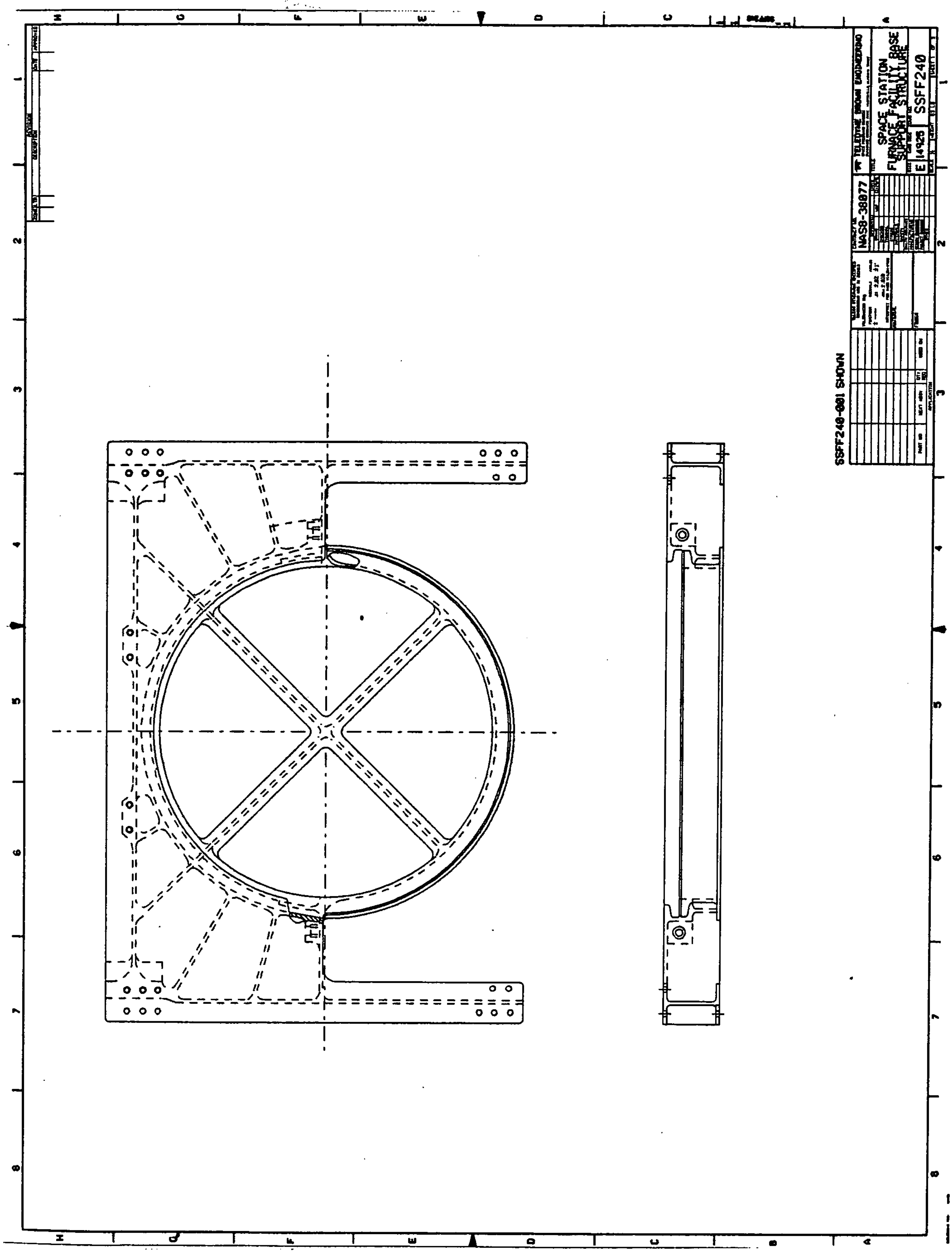


FIGURE 14. FURNACE SUPPORT STRUCTURE

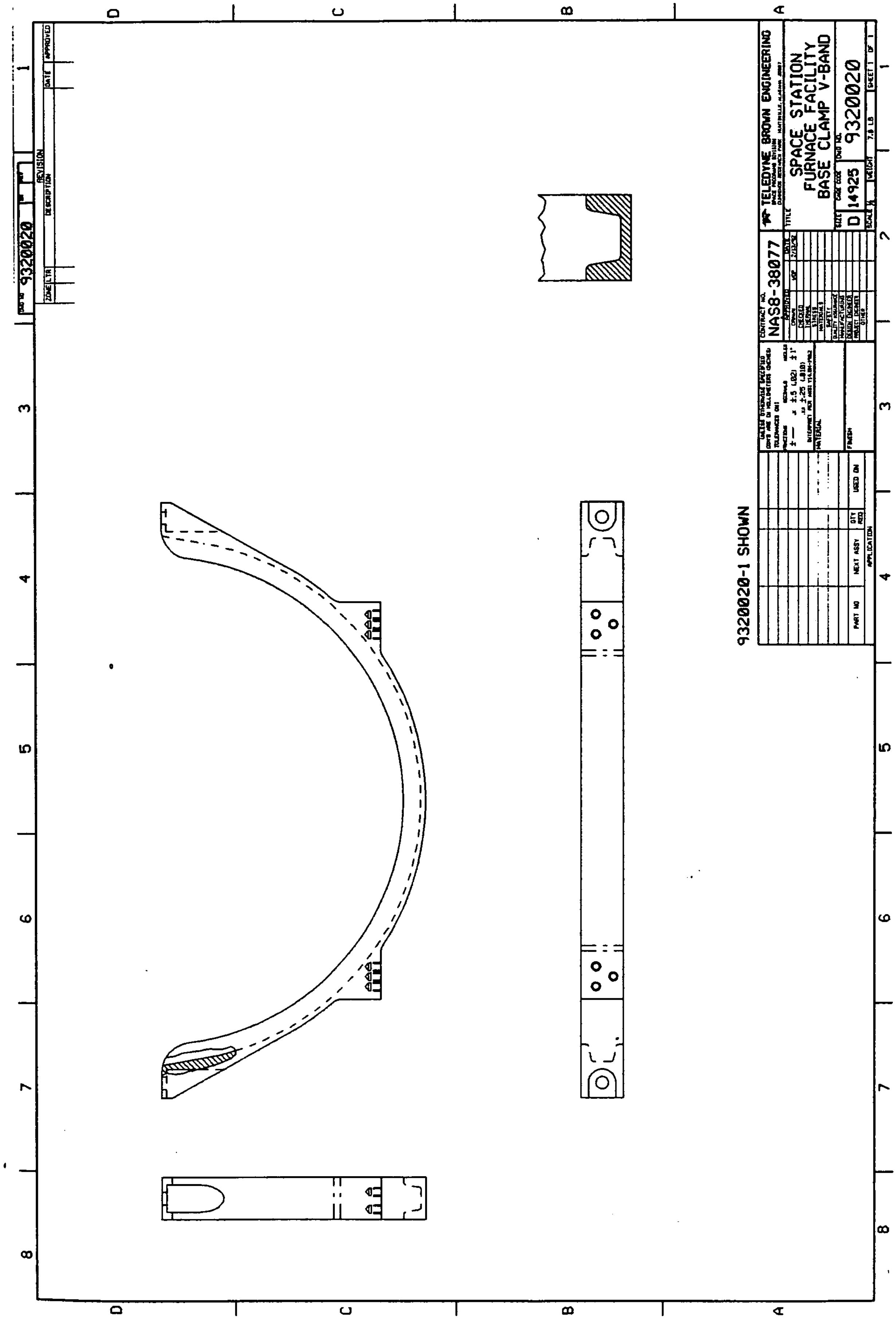


FIGURE 15. BASE CLAMP

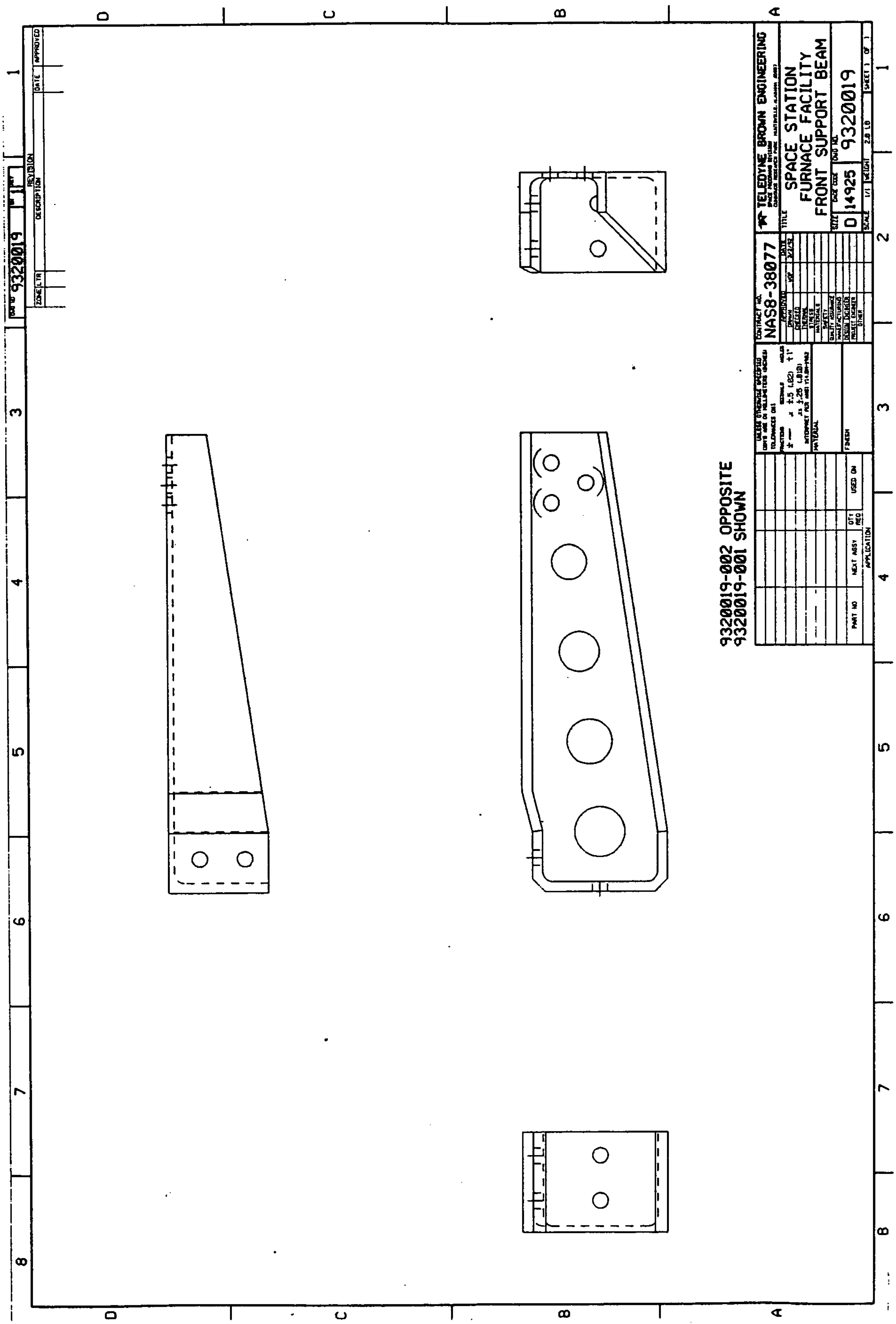


FIGURE 16. FRONT SUPPORT BEAM

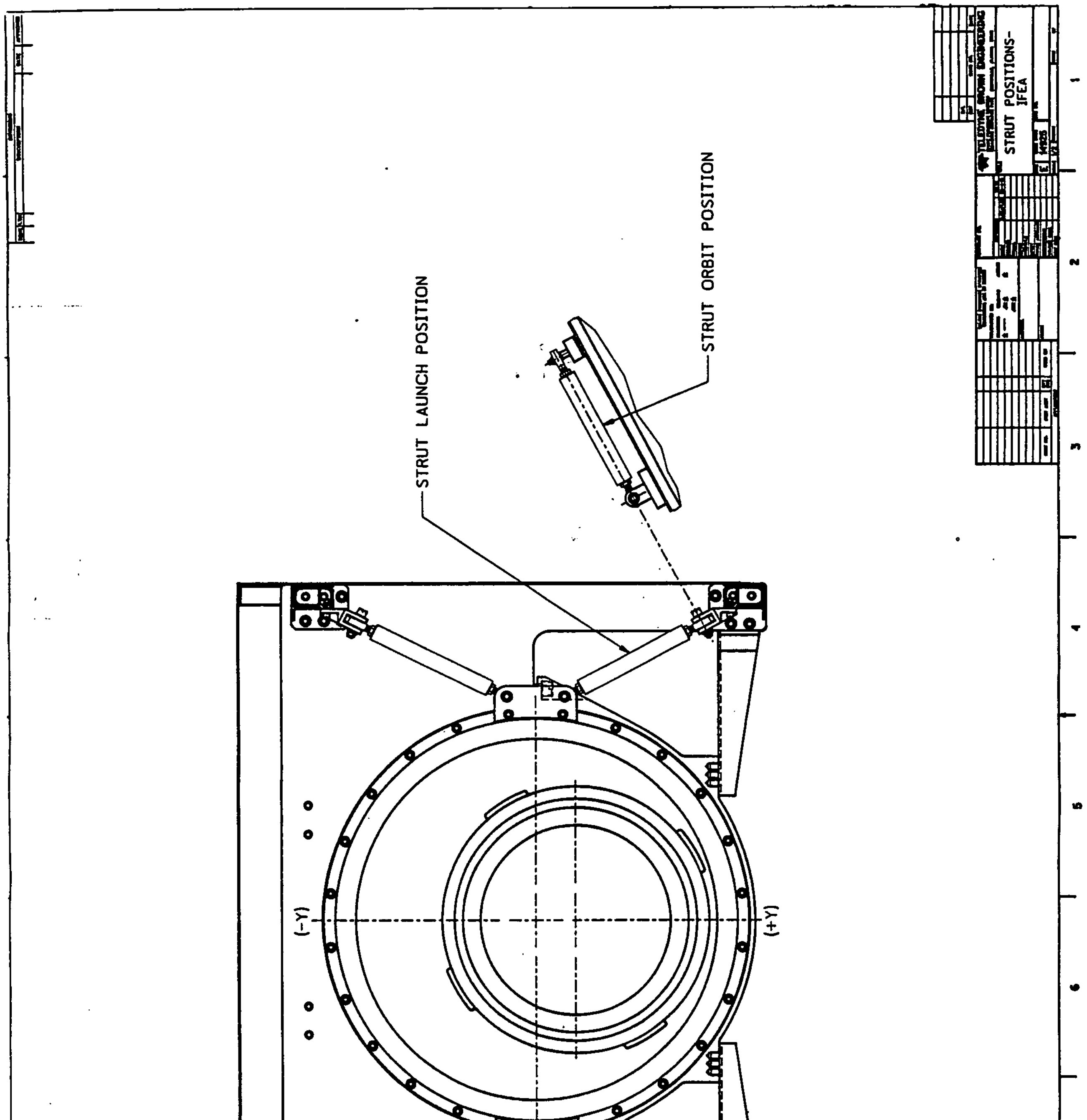


FIGURE 17. UPPER IFEA STRUTS

TABLE 3. SPACE STATION FURNACE FACILITY
FURNACE RACK DRAWING TREE

DRAWING TITLE	DRAWING NUMBER
Furnace Rack, Level 1 Assembly	9320001
Corner Post End Fitting	9320009
Lower Attach Fitting	9320012
Pivot Housing	9320013
Base Support Structure	9320018
Front Support Beam	9320019
Base Clamp V-Band	9320020
Equipment Frame Assembly	9320021

TABLE 4. SSFF ALUMINUM FURNACE RACK WEIGHT ESTIMATE

Component	Weight Est KG	(lbs)
Front Corner Posts	7.1	(15.6)
Post End Fittings	0.4	(0.9)
Rear Corner Posts	6.8	(14.9)
Horizontal Tubes	3.2	(7.0)
Tube End Fittings	0.4	(0.8)
Upper Attach Fittings & Mechanism	2.2	(4.8)
Lower Attach Fittings	2.1	(4.5)
Pivot Housings & Mechanism	0.9	(2.0)
Furnace Base Support Structure	24.1	(53.0)
Base Clamp Ring	3.2	(7.0)
Front Support Beams	1.8	(4.0)
Back Corner Bracket	0.1	(0.2)
Skin Support Angles	7.5	(16.6)
Side Access Panels	5.8	(12.9)
Rear Access Panel	5.3	(11.6)
Skin (0.060)	16.5	(36.4)
Skin Stiffeners	1.1	(2.5)
Cargo Tracks	1.6	(3.5)
Interface Panels	0.9	(2.0)
Interconnect Close Out Curtains	2.3	(5.0)
Rack Face Close Out	13.6	(30.0)
Fastener Allowance	1.8	(4.0)
Design Margin (10%)	10.9	(23.9)
Total	119.7	(263.3)

INTRODUCTION

This section includes a collection of reports from the trade studies and assessments required in the Space Station Furnace Facility Contract Statement of Work. These reports were delivered at various reviews, workshops, and meetings during the performance of the contract. The methodology and status of each trade was presented in viewgraph presentations at each meeting. Each report is comensurate with the conceptual design of the SSFF Core at the time of the report delivery. All reports prepared during Part 1, and so dated, reflect the conceptual design at the CoDR.

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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320RPT0010

REPROGRAMMING OF EXPERIMENT COMPUTERS TRADE STUDY FOR THE SPACE STATION FURNACE FACILITY

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

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1. INTRODUCTION

1.1 GENERAL

This document defines operational requirements necessary for orbital operations of the Space Station Furnace Facility (SSFF). This document includes the results of the engineering analysis effort to develop Space Station Freedom (SSF) mission operational scenarios for man-tended and permanently-manned operations. Also included in this report are the results of the engineering analysis effort to develop SSFF component and event related command lists, data output and downlink list, power circuit and demand lists, and crew activity lists. The mission requirements defined in this effort were based on the resources required by the Crystal Growth Furnace (CGF).

1.2 PURPOSE

The purpose of this document is to demonstrate flight systems operation of the Space Station Furnace Facility and to identify mission implications for the man-tended and permanently-manned period on the SSFF.

1.3 APPLICABLE DOCUMENTS

WP 01 D683-10496-1	Orbital Operations Requirements Analysis Data DR OP-16
WP 01 D683-10495-1	Systems Operations Scenarios DR OP-17
MSFC JA- 1437	Crystal Growth Furnace Payload Operating Procedure
320RPT0008	SSFF Subsystems Concept Reports Science Capabilities Requirements Document

2. APPROACH

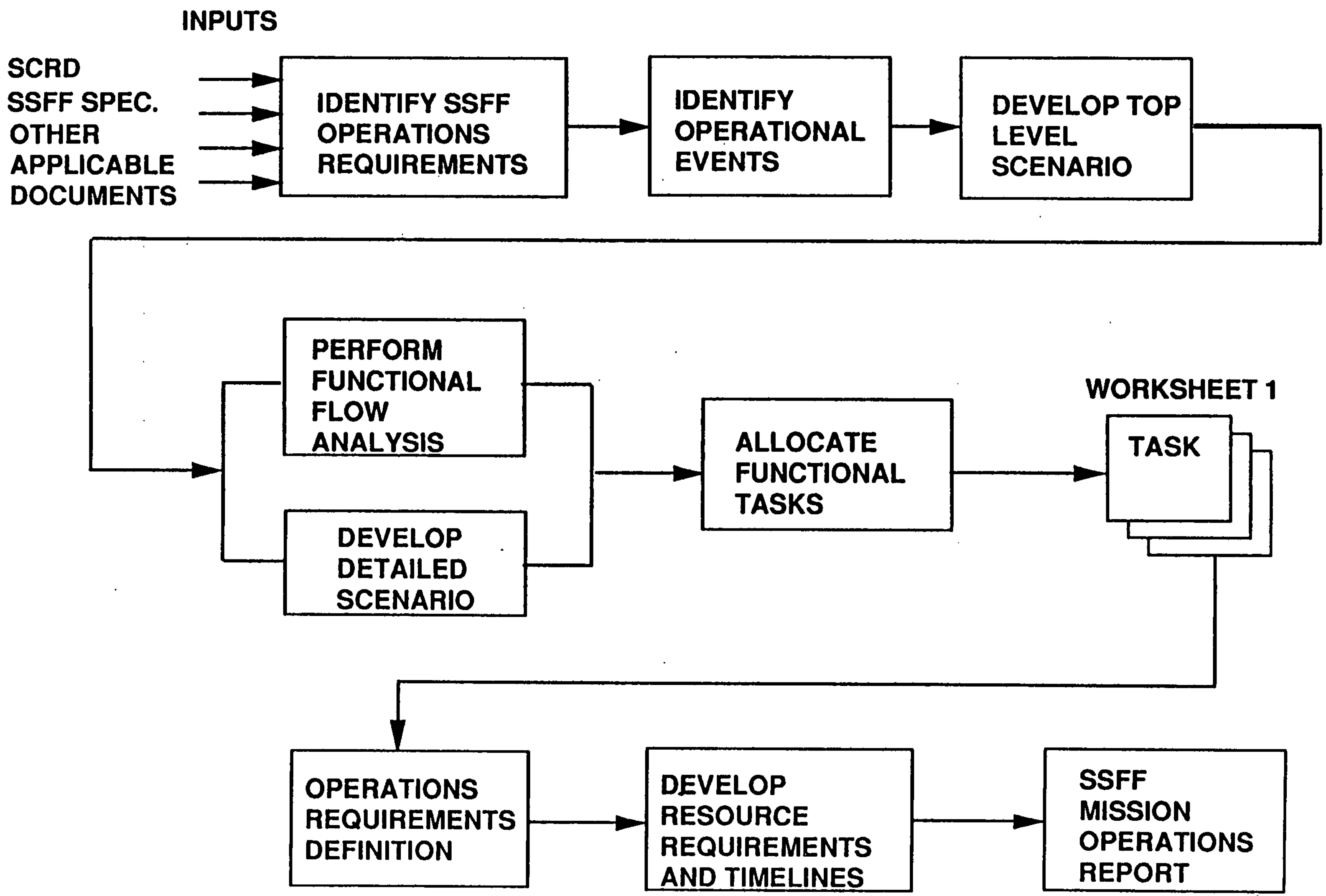
2.1 METHODOLOGY

The methodology used to develop WBS 1.4.3 Mission Operation Scenarios was derived from review of WP 01 D683-10496-1 Orbital Operations Requirements Analysis Data- DR OP-16 and D683-10495-1 WP01 Systems Operations Scenarios-DR OP-17 documentation. DR OP-16 and DR OP-17 define the WP01 prime contractor's understanding of the activities necessary for their support of orbital operations in the Space Station Freedom program by definition of the flight operations scenarios. DR OP-16 contains the operations requirements analyses performed to define these WP01 flight operations scenarios. DR OP-17 contains the results of operations requirements analyses performed on the scenario(s) defined in DR OP-16.

The mission operations analyses presented in this document were conducted following the methodology presented in Figure 2-1. SSFF operations requirements were developed from inputs of the Science Capabilities Requirements Document (SCRD), SSFF Specifications, Statement of Work, and other applicable documents. SSFF operational events were determined from analyses of the operations requirements and a top level scenario developed. The SSFF Operational Events and Top Level scenario are shown in Figure 2-2. It is from this scenario that functional flow analysis was performed. The functional flow analysis of the scenario is broken down to the lowest level of functional detail until the functions are expressed as tasks, from which operational requirements and support equipment are identified. Operational requirements are identified through the use of worksheets corresponding to each identified task. An operational requirement defines a capability which is needed in order for a given function to be performed. A baseline scenario is compiled from analyses of individual task descriptions and operational requirements identified for those tasks.

This approach in developing WBS 1.4.3 Mission Operations scenarios was decided upon to simplify development of the scenarios, to expedite concurrence through use of documentation familiar to NASA and to allow easy integration into developing WP 01 flight operations scenarios.

FIGURE 2-1 METHODOLOGY FLOW



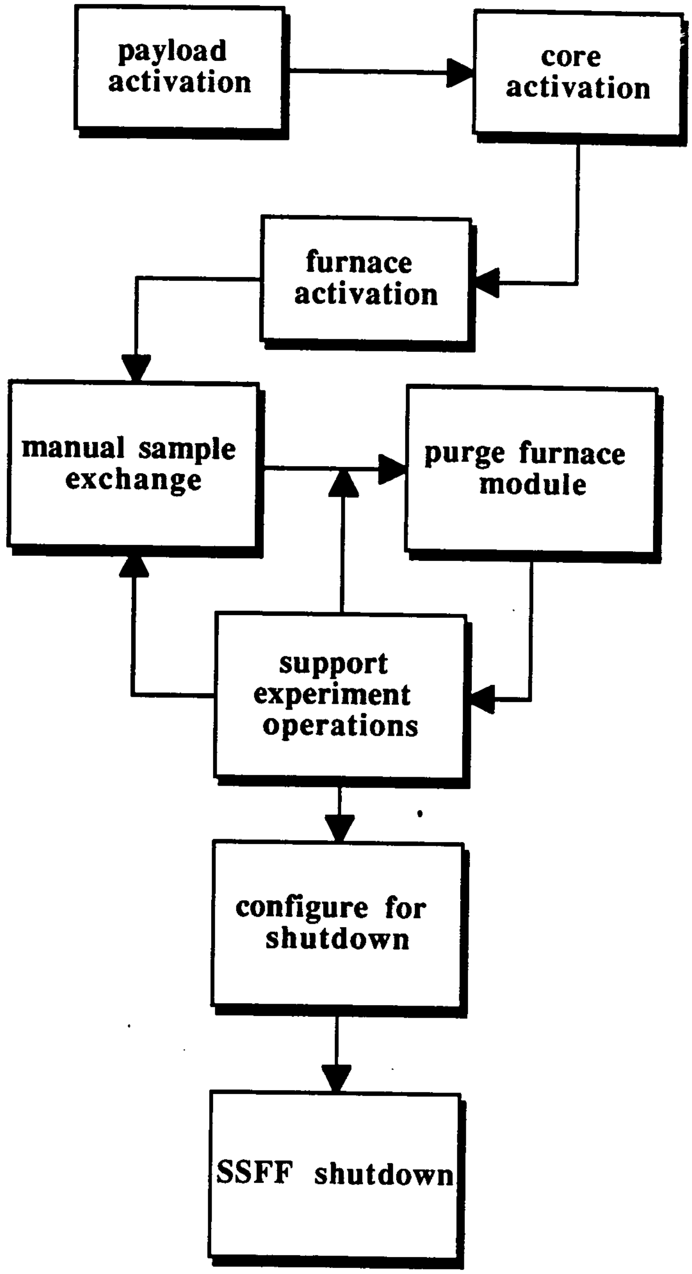


FIGURE 2-2. OPERATIONAL EVENTS AND TOP LEVEL SCENARIO

2.2 GROUNDRULES AND ASSUMPTIONS

Assumptions and groundrules are derived for the purpose of determining solutions concerning SSFF operations when actual data or hardware is not available. The Assumptions listed are for all scenarios referred to in this document. The Assumptions are also valid for the other scenarios generated in the Mission Operations Scenarios Document. Any additional Assumptions regarding specific scenarios in the Mission Operations Scenarios Document will be specified therein. The Assumptions for the Scenarios are listed by category in Table 2-1.

TABLE 2-1. ASSUMPTIONS AND GROUNDRULES

TOPIC	ASSUMPTIONS AND GROUNDRULES
SSFF Configuration	- The initial SSFF will be launched in the Mini-Pressurized Logistics Module (MPLM). - The initial SSFF Configuration will include the Core Rack Facility and Experiment Rack-1, one Furnace Module-1. - Furnace Module-1 requirements are estimated from the Crystal Growth Furnace (CGF) Module. - The first furnace will be configured for and include the provisions to Accommodate six (6) samples. - The SSFF Configuration will upgraded to include the Core Rack, two Experiment Racks, two Furnace Modules. - Furnace Module-2 will be a Programmable Multi- Zone Furnace Module (PMZF)
SSFF Interfaces	- All interfaces from SSF to SSFF are described in the ISPR ICD Rev 11 (August 15,1991). - All resources required by SSFF will be provided by Space Station Freedom (SSF) and reasonable access to these resources will be available.

TABLE 2-1 ASSUMPTIONS AND GROUNDRULES

TOPIC	ASSUMPTIONS AND GROUNDRULES
Assembly Operations	- SSFF installation will occur during Man-Tended Capability (MTC) phase of station operation and include a core rack and one experiment rack. - Additional Furnaces will be installed on later flights TBD.
SSFF Operation	- Furnace Module 1 will be the only furnace to be operating during Man-Tended Configuration. - During a MTC 90 day mission, samples will be processed upon crew departure from SSF to minimize vibration disturbances in the specimens. - During Permanently- Manned Configuration (PMC) two furnaces will be in operation. - PMZF is the second furnace module. - PMZF is modeled from the CGF resource requirements plus the addition of video equipment. - A furnace characterization sample will be the first sample to be run on every carousel during MTC and PMC.

TABLE 2-1 ASSUMPTIONS AND GROUNDRULES

TOPIC	ASSUMPTIONS AND GROUNDRULES
Internal Audio and Video	- Video and High Rate Recorder will not be installed into core until Furnace Module-2 is installed. - Video equipment is only considered in the second furnace module.
Samples	- The samples used in modeling are HgCdTe, HgZnTe, CdTe and GaAs.

3. SSFF OPERATIONS

3.1 OPERATIONS OVERVIEW

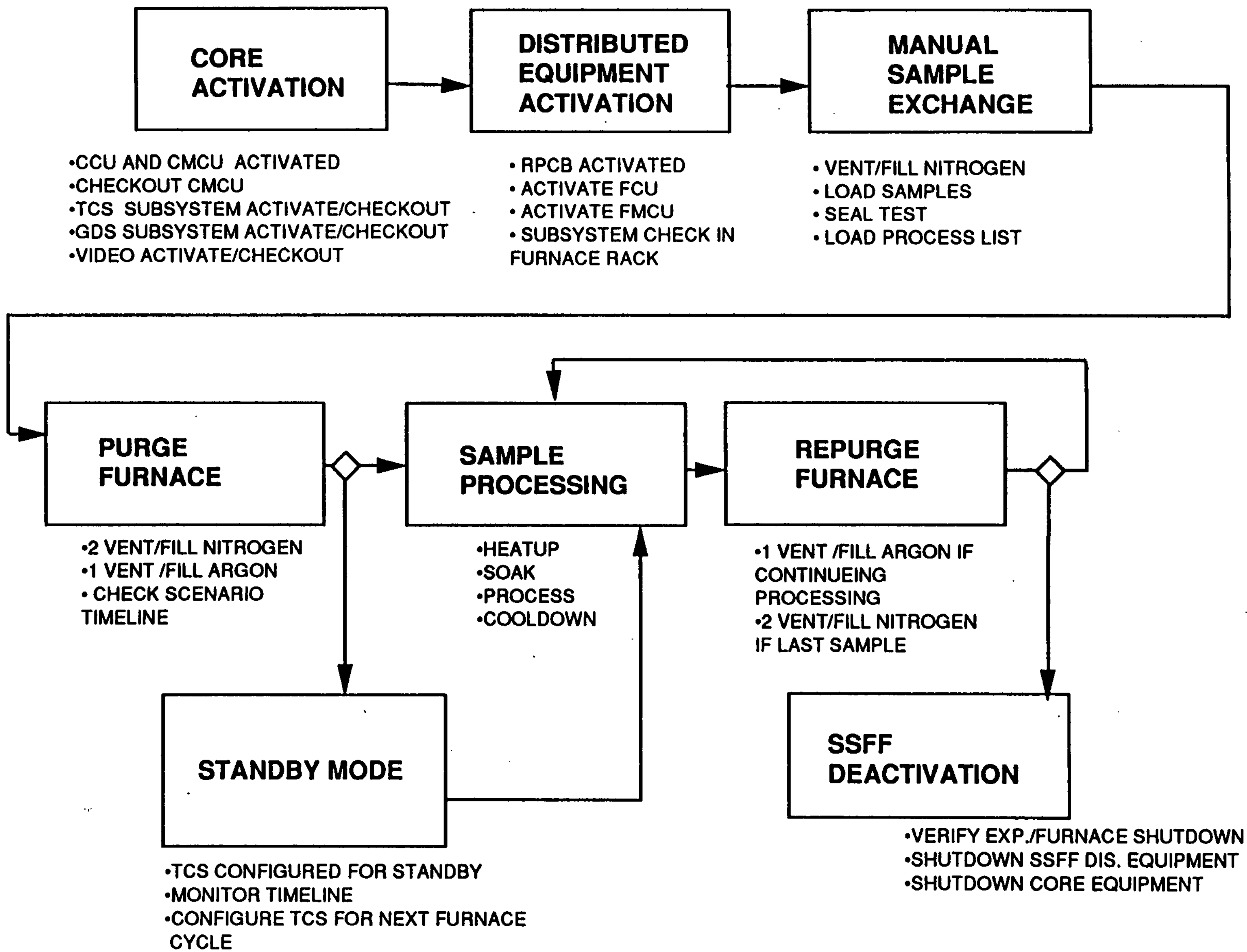
The SSFF consists of a core rack which will provide a set of standard support services to one or more furnace modules. The facility is presently configured to operate with two separate furnace modules. The variety of furnaces which could operate within SSFF will demand adaptability in the core to provide the necessary resources to operate each type of furnace. The normal operating flow for the SSFF is listed in Figure 3-1.

The operation of the SSFF consists of three phases: activation, processing and shutdown. The activation phase involves turning on equipment throughout the facility. This includes the core located equipment and the distributed equipment. After the activation phase is complete the SSFF then enters a Manual Sample Exchange (standby) mode where the subsystems have been configured and are waiting for resource and timeline availability. This mode allows the SSFF subsystems to remain in standby while the furnace module is in a safe configuration for sample loading.

The next phase is processing. After securing resources and timelining information the Data Management Subsystem (DMS) will send a signal to the furnace to initiate a power up sequence and start a processing cycle. Processing of the samples includes venting and purging of the furnace module by the Gas Distribution Subsystem (GDS). Upon completion of sample processing the carousel will then deliver another sample to be processed. A purge and backfill of the furnace chamber with clean processing gas will occur after three samples have been processed. Depending on degradation of ampoules and resource availability the amount of purge and backfills can be increased to provide a cleaner environment. Once a carousel (six samples/carousel) has been processed the facility returns to the standby mode.

At this point the facility can either continue to process samples (after receiving a new carousel) or enter the shutdown phase. The shutdown phase is essentially the activation phase but in reverse order. First the facility is configured by the DMS for shutdown, followed by distributed equipment shutdown then core equipment shutdown. To configure the facility for shutdown, the DMS verifies furnace position, furnace temperature, and furnace condition. Once the furnace is secure the Thermal Control Subsystem (TCS) then discontinues cooling flow to the distributed equipment. Immediately following this the power is shut down to all distributed equipment. Core equipment is then systematically reduced to the essential core equipment. The shutoff of the TCS pump, immediately followed by the Core Control Unit's notification to suspend resources from SSF completes the core equipmentshutdown. In order to continue processing samples the crew

FIGURE 3-1 NORMAL OPERATING FLOW



will be required to exchange set of samples.This will occur during permanently-manned capability From the standby mode, the crew would perform a manual sample exchange to process another set of samples. The process continues as before, processing samples in the carousel until it returns to standby mode. At this point an option exist again for shutdown or continued operation of the SSFF.

3.2 SUBSYSTEMS OPERATIONS DESCRIPTIONS

The SSFF can be broken down into four subsystems that monitor and control operations of the facility: the Data Management Subsystem (DMS), the Gas Distribution Subsystem (GDS), the Thermal Control Subsystem(TCS), and the Power Conditioning & Distribution Subsystem (PCDS). The following paragraphs briefly describe the operation of each of these subsystems.

The Data Management Subsystem contains the electronics necessary to monitor and control the subsystems. Other functions of the DMS include: monitoring the furnaces for temperature inputs via thermocouples, control furnace translation over the sample, video camera positioning and focus control, control of other actuators/effectors for the furnace, provide a communications link between the subsystems, store (and/or process) experiment data, and also provide an interface to Space Station Freedom DMS.

The Gas Distribution Subsystem (GDS) will provide an interface to the SSF Lab Nitrogen System (LNS) and Vacuum Exhaust System (VES). GN2 will be used as a purge gas to clean the furnace chamber while the vacuum vent line will be used to vent the furnace gases. A Contamination Monitoring System will be used by the GDS to determine if it is safe to vent the furnace gases to the VES. The GDS will also provide argon to the furnace modules as a process gas. The argon will be provided as an ORU and can be replaced by other desirable process gases. Control of the GDS is performed by the DMS.

The SSFF TCS water cooling loop collects heat from the furnace modules and subsystem electronics. The heat is then transferred to the Space Station Thermal Control System via the core rack heat exchanger. During operation, coolant is directed in a single cooling line from the pump package outlet through the heat exchanger, then branches into a three-branch parallel system with each rack receiving one cooling line. The rack lines branch into two parallel legs to flow through coldplate mounted equipment. In this configuration the TCS contains a total of six parallel legs (two in each rack). The cooling lines in the experiment racks rejoin into one line before entering the furnace modules. This enables the entire cooling load to be directed to the modules. After leaving the racks the cooling lines are rejoined into one line in the core rack completing the flow path of the cooling loop.

The baseline concept of the PCDS provides for SSFF power to be brought into the facility at the core rack. From here the power is then distributed to core subsystem equipment, furnace rack equipment, and the furnace modules. The majority of the PCDS equipment is centralized in the core rack. Secondary distribution equipment in the furnace racks allows for growth of the PCDS by providing a point at which power can be brought into the SSFF through the furnace rack. Power distribution and control will be controlled by the SSFF DMS.

3.3 EQUIPMENT SAFING

The operation of SSFF during Man-tended Configuration allows for extensive operation with no crew present. This section describes the procedures for ensuring equipment safety and redundancy in the SSFF subsystems if a possible emergency should arise. While the SSFF may be capable of continued operation, the SSFF procedure for all cases of potential hazards is termination of processing and a complete shutdown of the Furnace Facility. The Data Management Subsystem will be responsible for initializing a shutdown procedure, when required, and will be supported by the other subsystems within the facility. The Data Management Subsystem will be capable of detecting and isolating safety issues as they occur. Redundancy within individual subsystems has been incorporated in the subsystem design as much as practical, however each subsystem is designed so that it may be reconfigured and/or shutdown via DMS. Critical components have been identified for each of the subsystems and the relative hazard for failure of this component has been assessed. The redundancy of equipment and areas of potential hazards are addressed below by each subsystem.

POWER CONDITIONING AND DISTRIBUTION SAFING

The SSFF PCDS will address safety in two areas. 1) Safe shutdown of the SSFF and 2) Protection of internal SSFF subsystems from internal failures.

The PCDS will support safe shutdown of the SSFF subsystems by providing an essentials power supply in each rack. The essentials power supply combines two independent feeds originating from SSF EPS while maintaining all the required isolation and protection requirements. This power supply will provide power to any equipment necessary for the safe shutdown of the SSFF. Since it is assumed that at no time will both SSF buses be lost simultaneously, the essentials power supply will ensure that safing power is at all times available to essential shutdown equipment. The essentials power supply ensures that SSFF will meet this requirement.

The PCDS will protect SSFF equipment from internal failures through circuit protection. Current limited switches will isolate failed equipment from other healthy equipment on the power distribution network. This will prevent a single failure from impacting the entire facility

electrically. Status indicators on switches will notify DMS when components have been tripped off the network so that appropriate action can be initiated.

No safety related impacts are foreseen to be generated by the baseline PCDS concept other than those normally associated with electrical power systems.

THERMAL CONTROL SUBSYSTEM SAFING

The Thermal Control Subsystem has no identifiable safety concerns other than those normally associated with this type of system. Typical hazards and controls to be addressed are listed below:

- Release of water into cabin, furnace, etc.. Prevented by appropriate design safety margins based on maximum design pressure (MDP) for all plumbing components.
- Fail-safe design for loss of cooling to control potential hazards of fire, overpressurization and touch temperature exceedances. Controls will include automatic removal of electrical power when loss of cooling is sensed and use of accumulator to accommodate any boiling or vaporization of water from an overheated furnace.
- Touch temperature control for surfaces accessible to the crew during normal and contingency operations. During normal operations, active cooling should maintain surface temperatures below 45°C. For contingency operations (e.g., loss of cooling, furnace re-entry), temperature indicator labels, malfunction/operational procedures with warnings, sample cooldown times as determined by test, etc., are appropriate hazard control measures.
- Structural failure of rotating devices (e.g., pumps) with possible release of fragments. Containment devices, protective devices such as thermal overload sensors and over-speed control, plus adequate structural design including application of fracture control requirements, are appropriate control measures.

GAS DISTRIBUTION SUBSYSTEM SAFING

The GDS conceptual design presents several significant safety concerns for the SSF and its crew. Some of the more hazardous safety issues associated with the GDS design include:

- Use of high pressure gasses with the potential for explosive rupture with fragments. Typical hazard control measures for high pressure systems include designing pressure vessels to MIL-STD-1522A which requires applications of fracture control techniques. Lines and fittings will be designed to appropriate safety factors of 2.5 ultimate based on the system maximum design pressure (MDP). When regulators, relief valves, etc., are used to determine MDP, the system will have a level of failure tolerance appropriate to the hazard classification level.
- Overpressure control of high temperature furnaces processing hazardous experiment sample materials which must be contained to preclude crew exposure to toxic materials and/or release of materials corrosive to SSF hardware. Hazard controls will include provisions for two

pressure relief devices on each furnace module (ideally , the issue of "at will" access to the SSF (Vacuum Exhaust System) VES must be resolved to make the use of relief valves a viable hazard control. (Note: the furnace pressure control schemes discussed in para. 3.2.1.2 are for small pressure fluctuations and are not considered as hazard controls).

- The necessity for venting to space through the SSF VES which constrained to accept only "non-hazardous" furnace exhaust products. Obviously, :vent "at will" is not feasible for the furnace modules due to the hazardous nature of many experiment sample materials that are planned to be processed (e.g., mercury). The approach proposed in the present conceptual design (contamination monitoring and filtration of potential furnace exhaust products, combined with the capability to shutdown and seal the furnace if necessary) is acceptable as a hazard control. This assumes that the technology is feasible.
- Use of rotating devices whose structural failure could result is release of fragments. Structural failure of high speed rotating devices such as compressors are typically controlled by containment devices, protective devices such as overspeed control, plus adequate structural design, including application of fracture control techniques.

DATA MANAGEMENT SUBSYSTEM SAFING

The SSFF Data Management Subsystem will accommodate this requirement through the use of redundant data buses and multiple processors involved in the monitoring and control of the facility. The primary method of safety backup control is the approach that the furnaces are monitored by both the Furnace Control Units and the Distributed Core Monitor Units (which also serve to monitor the Core services being provided to the furnaces (Thermal, Gas, and Power)). The resulting data is transmitted back via separate data paths (Experiment DMS Bus and the Core DMS Bus) and the data comes together at the Core Control Unit which issues commands to the Core Subsystem Services via the CMCU (which is providing monitoring and control of the other subsystem Core Services). Through this method, the SSFF has provided redundant monitoring and multiple processor verification of the command stream to the services.

As an added safety measure (in the event of CCU failure), there are two added scenarios that are implemented. All of the Core Subsystem interfaces (TCS, GDS, and PDS) are resident on the 1553 Core DMS bus, for good reason.

If the CCU were to issue (or not issue) commands that provide for the safe operation of the facility, through dynamic bus control (one of the modes of 1553) either the CMCU or the DCMU can issue commands to provide control of the Core DMS Bus limited to the safing of the facility. This would involve safe modes for the PDS, TCS, and GDS systems, and therefore safe the facility (if necessary, the power could be pulled on components causing problems).

In the event that the current Bus Controller would not release the Core DMS Bus to the secondary Bus Controller (although illegal by 1553 protocol) a hardwire control over all the transceiver chip sets in all residents on the bus is implemented to provide a non-interruptable method of terminating broadcast privileges of the current Bus Controller and cause the unit in

question to be set into an listen only capacity. In this mode, the secondary master can implement a safe shutdown of the facility.

Through these methods safe operation of the SSFF is insured to meet the requirements for operation aboard Space Station Freedom.

4. SSFF OPERATIONS SCENARIOS

4.1 INTRODUCTION

The generated SSFF scenarios are based on two configurations: man-tended capability (MTC) and permanently-manned capabilities (PMC). MTC configuration will have the crew available for the first 15 days of a 90 day mission. PMC will include the crew participation throughout a 90 day mission. The actual operation of the SSFF will remain similar throughout both the MTC and PMC scenarios. Operation of the SSFF is completely automated, therefore crew interaction with the SSFF is limited in both MTC and PMC. Manual exchange of samples and the enhancement of visual capabilities from the crew will encompass the majority of the crews activities. Both MTC and PMC scenarios developed herein demonstrate crew interactions with the SSFF.

Samples used in the scenarios are based on Crystal Growth Furnace (CGF) samples, which include HgCdTe, HgZnTe, GaAs, and CdTe. The samples were used to provide accurate data for modeling resource requirements, but do not reflect the only samples that can be processed by SSFF. The samples were categorized by processing time, to aid in the development of as many types of scenarios as possible. The categories used were long samples and short samples. Samples that are more than thirty hours in processing time are referred to as long samples. Samples requiring less than thirty hours are referred to as short samples. By selecting different combinations of long and short samples, a generated scenario (or one part of the scenario) can demonstrate typical SSFF operations.

4.2 MAN-TENDED CONFIGURATION

4.2.1 Introduction

The MTC scenarios were developed with the intent of showing the interaction between SSFF and the crew as well as to demonstrate system functionality. Crew interaction would be required during the first 15 days for sample loading and checkout of the SSFF. Sample processing would occur upon crew departure from SSF to minimize any vibrations. The samples processed are HgCdTe, HgZnTe, GaAs, and CdTe in a Module #1 Furnace. The MTC scenarios listed below are selected to demonstrate possible envelope limits in requirements. Specific mission profiles can be generated by combining various scenarios.

4.2.2 MTC Scenario Descriptions

Scenario #1 is used as a baseline for SSFF operations. The first sample is a characterization sample for the furnace. The remaining five samples are HgCdTe, HgZnTe, GaAs, CdTe and HgZnTe. HgZnTe is repeated to demonstrate typical SSFF operation with a six sample carousel. The processing time for completion of all samples does not require the entire 90 day mission.

Scenario #2 demonstrates a typical mission under normal SSFF operations. The samples are again HgCdTe, HgZnTe, GaAs, CdTe, and a characterization sample. HgZnTe is again repeated. However, the run time is lengthened to complete the processing of a 12-15 cm sample. This time increase accounts for 42 additional days per HgZnTe sample. This scenario will fill an entire 90 day mission cycle.

Scenario #3 represents the functionality of SSFF in handling combinations of long and short processing times. It also provides data for potential combinations of samples. A characterization sample, HgCdTe, HgZnTe, GaAs, and CdTe are the samples processed. The first three samples processed are a characterization sample, CdTe and GaAs and require a short, a long and a short processing time respectively. The three remaining samples (CdTe, HgCdTe and GaAs) are subsequentially processed in a random order. Random order refers to processing a long or short sample followed by two sample of opposite processing duration. (e.g. short, long, long)

Scenario #4 reflects a possible scenario of processing a set of six samples during the first 15 days of MTC. The samples used are a characterization sample, GaAs and HgCdTe. GaAs and HgCdTe are repeated for the remaining five samples because of their short processing times.

Scenario #5 exhibits the possibility of an interruption in processing a carousel of samples. The type of samples processed are HgCdTe, HgZnTe (extended processing time), HgZnTe, GaAs, and CdTe. They are processed in random order. The scenario includes a SSFF shutdown procedure upon request from SSF. This shutdown request will occur before all of the samples can be processed.

Scenario #6 will demonstrate a possible procedure for equipment safing. The type of samples processed are the same as in Scenario #5. The scenario will include a SSFF shutdown procedure that occurs as the result of a loss of one SSF power bus.

Scenario #7 displays a delayed time increment for the possible reprogramming of furnace parameters. The reprogramming task occurs after completion of the second sample. The SSFF remains in standby during a 20 minute delay for reprogramming of the processing parameters. The type of samples processed are again the same as in Scenario #5.

TABLE 4-1 MTC SCENARIO PARAMETERS

Scenario #	Samples Processed	Sample process time (hrs)	Times the sample was processed	Total # of Samples Processed per furnace (includes 1 characterization sample)	Objective
1	HgZnTe	152.7	2	6	Demonstrates Baseline
	HgZnTe*	1018.59	0		
	CdTe	94.9	1		
	HgCdTe	16.5	1		
	GaAs	27.2	1		
2	HgZnTe	152.7	1	6	Demonstrates Typical Mission
	HgZnTe*	1018.59	1		
	CdTe	94.9	2		
	HgCdTe	16.5	1		
	GaAs	27.2	0		
3	HgZnTe	152.7	1	6	Demonstrates Combinations of Samples
	HgZnTe*	1018.59	1		
	CdTe	94.9	1		
	HgCdTe	16.5	1		
	GaAs	27.2	1		
4	HgZnTe	152.7	0	6	Demonstrates MTC "Crew on Board" Processing
	HgZnTe*	1018.59	0		
	CdTe	94.9	0		
	HgCdTe	16.5	2		
	GaAs	27.2	3		
5	HgZnTe	152.7	1	6	Demonstrates Interrupted Processing
	HgZnTe*	1018.59	1		
	CdTe	94.9	1		
	HgCdTe	16.5	1		
	GaAs	27.2	1		
6	HgZnTe	152.7	1	6	Demonstrates Equipment Safing
	HgZnTe*	1018.59	1		
	CdTe	94.9	1		
	HgCdTe	16.5	1		
	GaAs	27.2	1		
7	HgZnTe	152.7	1	6	Demonstrates Reprogramming of Run Specific Data
	HgZnTe*	1018.59	1		
	CdTe	94.9	1		
	HgCdTe	16.5	1		
	GaAs	27.2	1		

* includes Extended HgZnTe Sample

4.3 PERMANENTLY-MANNED CONFIGURATION

4.3.1 Introduction

The permanently-manned scenarios were developed to show the interaction between the SSFF and the crew during a 90 day mission. Crew interaction could be utilized any time during a 90 day mission. Permanently-manned scenarios include the addition of Furnace Module #2 , a Programmable Multi-Zone Furnace (PMZF). The model used for the PMZF furnace is based on the CGF furnace plus resource requirements available for optional video equipment. The samples processed in Furnace Module #2 are a furnace characterization sample , HgCdTe, HgZnTe, GaAs, and CdTe. The PMC scenarios are similar to the previous MTC scenarios in that the actual operation of the furnaces remain the same, however, the scenarios will demonstrate overlapping furnace operation and reflect total power, crew and resource levels for both furnaces. These scenarios are selected to identify extreme cases for furnace operation. Listed below is a description of eight scenarios generated for PMC configuration.

4.3.2 PMC Scenario Descriptions

Scenario #8 is used as a baseline to demonstrate normal SSFF operations with two furnaces. The first sample in each furnace is a characterization sample. The remaining five samples are HgCdTe, HgZnTe, GaAs, CdTe, and HgZnTe. HgZnTe is repeated in both furnaces to demonstrate typical operations using a six sample carousel. Once the initial six samples have been processed, the crew will load the furnaces with another six samples to utilize an entire 90 day mission.

Scenario #9 demonstrates the adaptability of SSFF to handle samples requiring extended processing times while minimizing crew time. The time for processing one of the samples of HgZnTe is extended in both furnaces to allow processing of all samples to be completed within the 90 day mission. As a results of the extended processing times no carousel exchange is needed.

Scenario #10 illustrates the maximum use of crew time. Furnace Module #1 and Furnace Module #2 process the same samples used in Scenario #4. These samples are GaAs and HgCdTe and require extremely short processing time. Upon completion of a carousel, the crew will exchange samples. The short processing cycles demand extensive crew time for changing samples. This scenario will demonstrate a total

Scenario #11 portrays combinations of long and short processing times in both furnaces. The model purposely allowed peak power to be obtained in both Furnace Modules simultaneously. It was assumed that SSF mission timelines would try to avoid this scenario but that there was a possibility of it occurring. The data generated by this scenario depicts peak power requirements

occurring with two furnace operation for these type of samples. Furnace Module #1 and Furnace Module #2 will process two samples of CdTe, GaAs, HgZnTe, and an extended sample of HgZnTe.

Scenario #12 exhibits the interruption of one furnace from processing a complete carousel of samples. This scenario includes two samples of CdTe, a sample of HgCdTe, a sample of HgZnTe and an extended sample of HgZnTe repeated for each furnace. This scenario includes a SSFF shutdown procedure for one furnace upon request from SSF. This shutdown request will occur before all of the samples can be processed in that furnace module. The other furnace module will remain operating. This scenario is modeled to demonstrate a possible request from SSF reduce power consumption.

Scenario #13 demonstrates possible equipment safing for SSFF. Both furnaces are interrupted as a result of a loss of power to one bus. Both furnaces process the same type samples that were processed in scenario five.

Scenario #14 displays a short delayed time increment for the possible reprogramming of furnace parameters. One furnace exhibits a reprogramming task while the other furnace operates normally. The type of samples processed are the same as in scenario five.

Scenario #15 displays a short delay in processing for Furnace Module #1 and an extended delay in processing for Furnace Module #2. This reflects a scenario in reprogramming run specific data for furnaces. The extended delay due to constraints in the ability to uplink new software is a possibility. The type of samples processed are again the same as in scenario five.

TABLE 4-2 PMC SCENARIO PARAMETERS

Scenario #	Samples Processed	Sample process time (hrs)	No. of Times the sample was processed in Furnace Module #1	Times the sample was processed in Furnace Module #2	Total # of Samples Processed per furnace (includes 1 characterization sample per MSE)	Objective
8	HgZnTe	152.7	7	7	24	Demonstrates Baseline
	HgZnTe*	1018.59	0	0		
	CdTe	94.9	4	4		
	HgCdTe	16.5	5	5		
	GaAs	27.2	4	4		
9	HgZnTe	152.7	1	1	6	Demonstrates Minimium Crew Time
	HgZnTe*	1018.59	1	1		
	CdTe	94.9	2	2		
	HgCdTe	16.5	1	1		
	GaAs	27.2	0	0		
10	HgZnTe	152.7	0	0	96	Demonstrates Maximum Crew Time
	HgZnTe*	1018.59	0	0		
	CdTe	94.9	0	0		
	HgCdTe	16.5	48	48		
	GaAs	27.2	32	32		
11	HgZnTe	152.7	1	1	6	Demonstrates Peak Resource Requirements
	HgZnTe*	1018.59	1	1		
	CdTe	94.9	2	2		
	HgCdTe	16.5	0	0		
	GaAs	27.2	1	1		
12	HgZnTe	152.7	1	1	6	Demonstrates Interrupted Processing
	HgZnTe*	1018.59	1	1		
	CdTe	94.9	2	2		
	HgCdTe	16.5	1	1		
	GaAs	27.2	0	0		
13	HgZnTe	152.7	1	1	6	Demonstrates Equipment Safing
	HgZnTe*	1018.59	1	1		
	CdTe	94.9	2	2		
	HgCdTe	16.5	1	1		
	GaAs	27.2	0	0		
14	HgZnTe	152.7	1	1	6	Demonstrates Reprogramming of Run Specific Data
	HgZnTe*	1018.59	1	1		
	CdTe	94.9	2	2		
	HgCdTe	16.5	1	1		
	GaAs	27.2	0	0		
15	HgZnTe	152.7	1	1	6	Demonstrates Extended Reprogramming of Run Specific Data
	HgZnTe*	1018.59	1	1		
	CdTe	94.9	2	2		
	HgCdTe	16.5	1	1		
	GaAs	27.2	0	0		

* includes Extended HgZnTe Sample

5. OPERATIONS ANALYSIS

5.1 FUNCTIONAL FLOW ANALYSES

This section includes the functional flow analyses data. The functional flows illustrate the procedures which are required for normal check-out and operation of SSFF. The functional flows are broken down into low levels of functional details until specific tasks are identified. It is from these flows that operational requirements are derived and traceability is maintained throughout the analysis. The top level functional flow for a generic scenario is shown in Figure 5-1. The detailed functional flow analysis for this same scenario is contained in Table 5-1. An outline of the flow detailed to the level of functional tasks is shown in Table 5-2. Some tasks have been combined to meet the minimum time constraints used in modeling.

5.2 OPERATIONS RESOURCE REQUIREMENTS ANALYSES

This section includes the Operations Resource Requirements Analyses which defines the resources used for the normal operation of SSFF. From the Functional Flow Analyses functional tasks are determined. These tasks are analyzed for the requirements needed for completion. This is accomplished through the use of worksheets corresponding to each task. Power, Crew, Thermal, and Data resources are each determined from these worksheets. Since the tasks for operation of SSFF remain similar for all scenarios, the resources were determined for a generic scenario. The resources required in support of experiment processing are different depending on sample type. Therefore, the resources required for this step of the scenario will be listed in Appendix A for each specific scenario. The event related and component list for a generic scenarios are shown in Table 5-3. The Resources (Power circuit and demand, Data output, Thermal Requirements) list for the generic scenario is shown in Table 5-4. The crew activity lists for the baseline scenarios shown in Table 5-5. The MTC and PMC generated scenario data is compiled in Appendix A.

5.3 OPERATIONS TIMELINE ANALYSES

This section includes the Operations Timeline Analyses. An event related timeline for the Baseline operational scenario is shown in Table 5-6. This timeline relates the Functional flow events for the normal operation of SSFF to actual time and day occurrence in a proposed 90 day mission. This timeline is shown for a baseline scenario only. Other scenario timelines for different sample configurations are included in Appendix A.

FIGURE 5-1 TOP LEVEL FUNCTIONAL FLOW

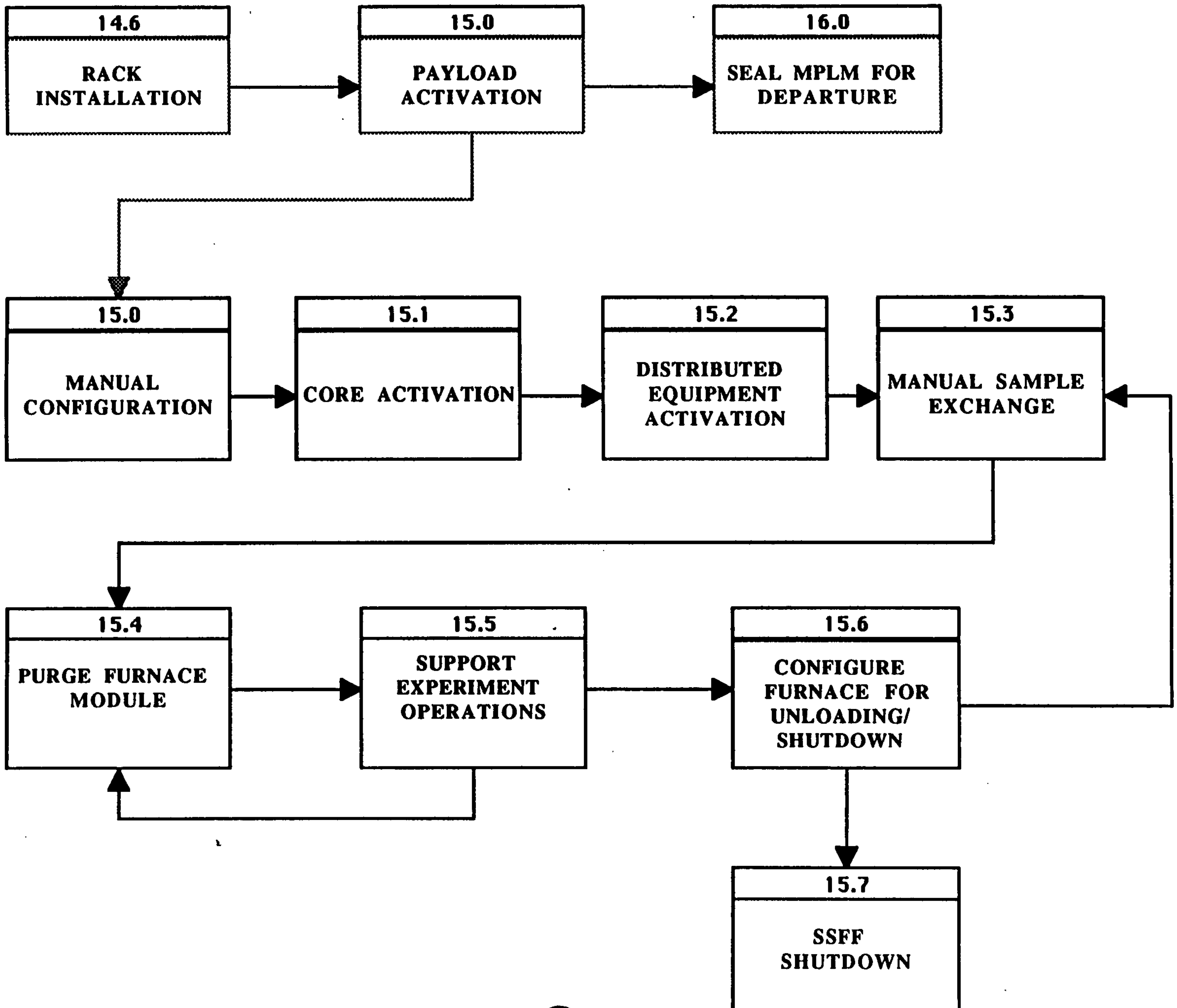


TABLE 5-1 FUNCTIONAL FLOW (Sheet 1 of 7)

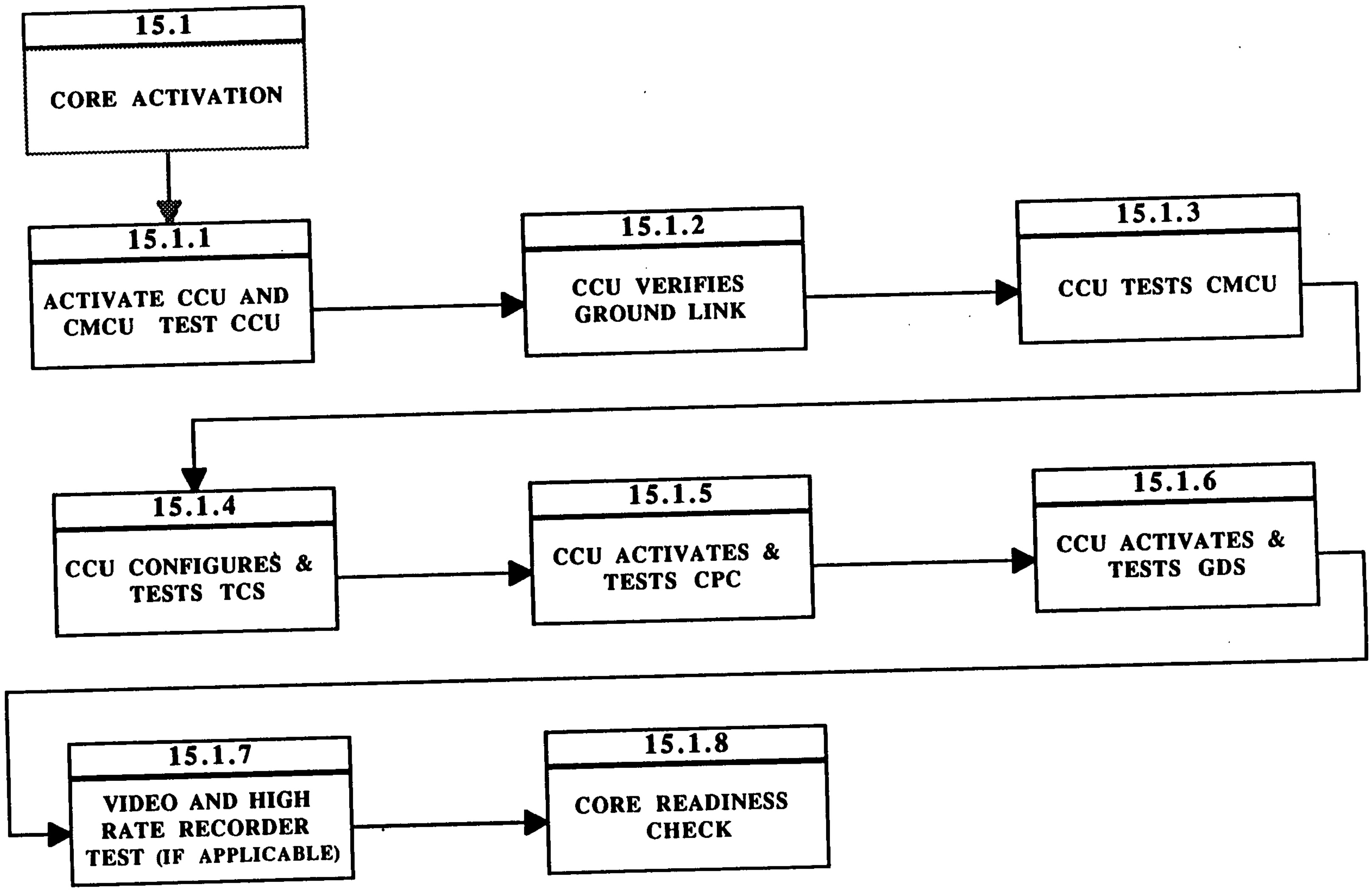


TABLE 5-1, FUNCTIONAL FLOW (Sheet 2 of 7)

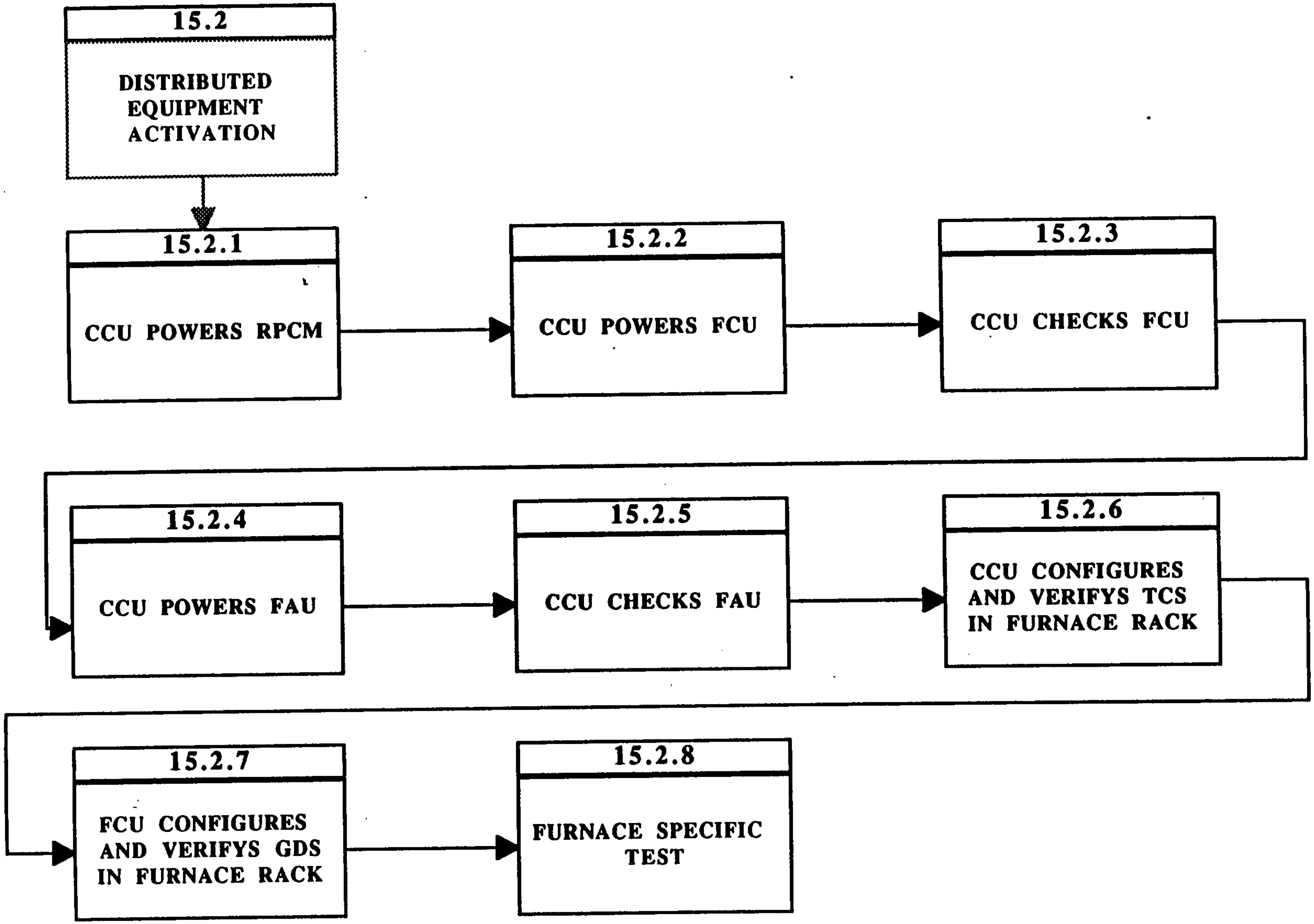


TABLE 5-1, FUNCTIONAL FLOW (Sheet 3 of 7)

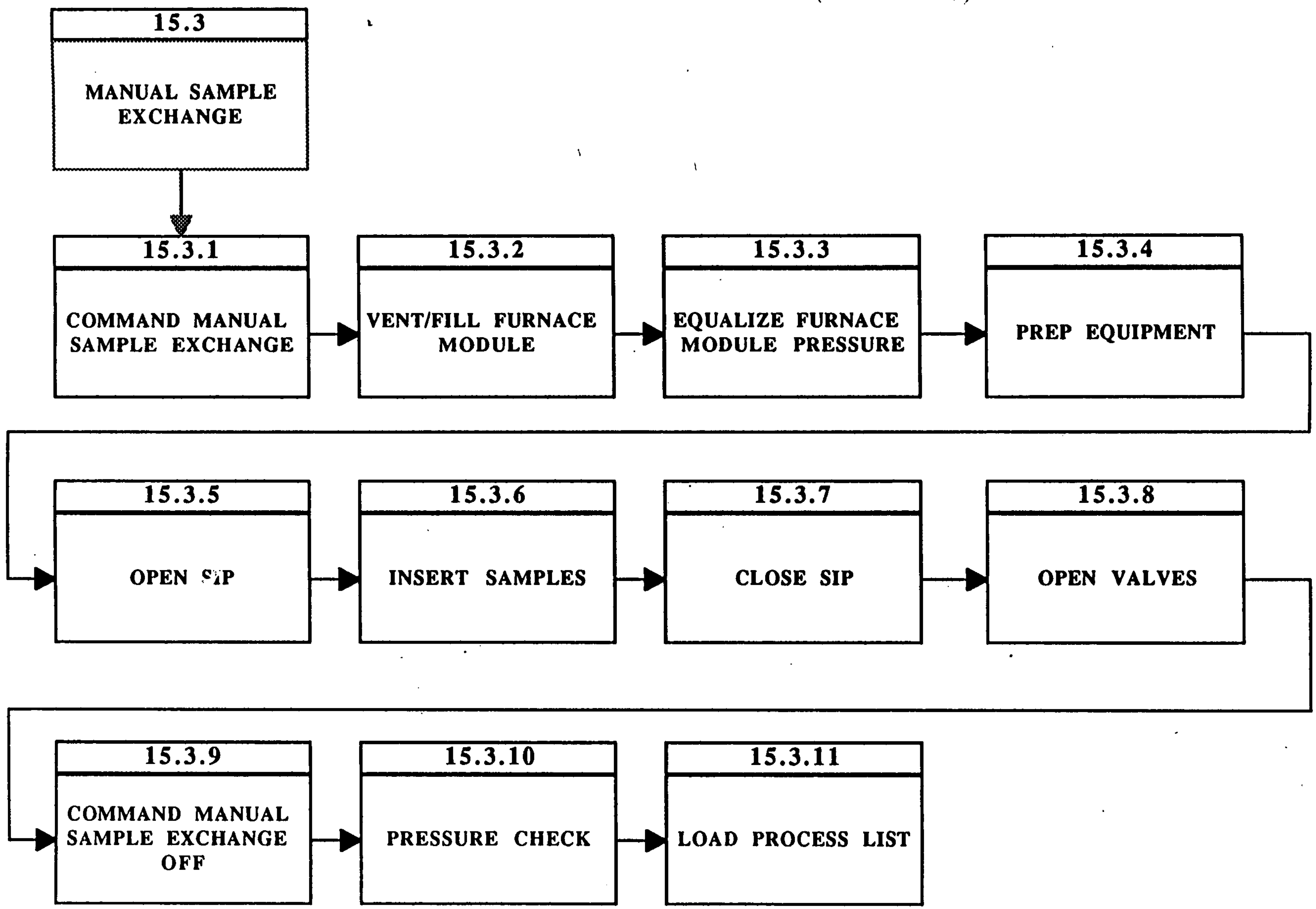


TABLE 5-1, FUNCTIONAL FLOW (Sheet 4 of 7)

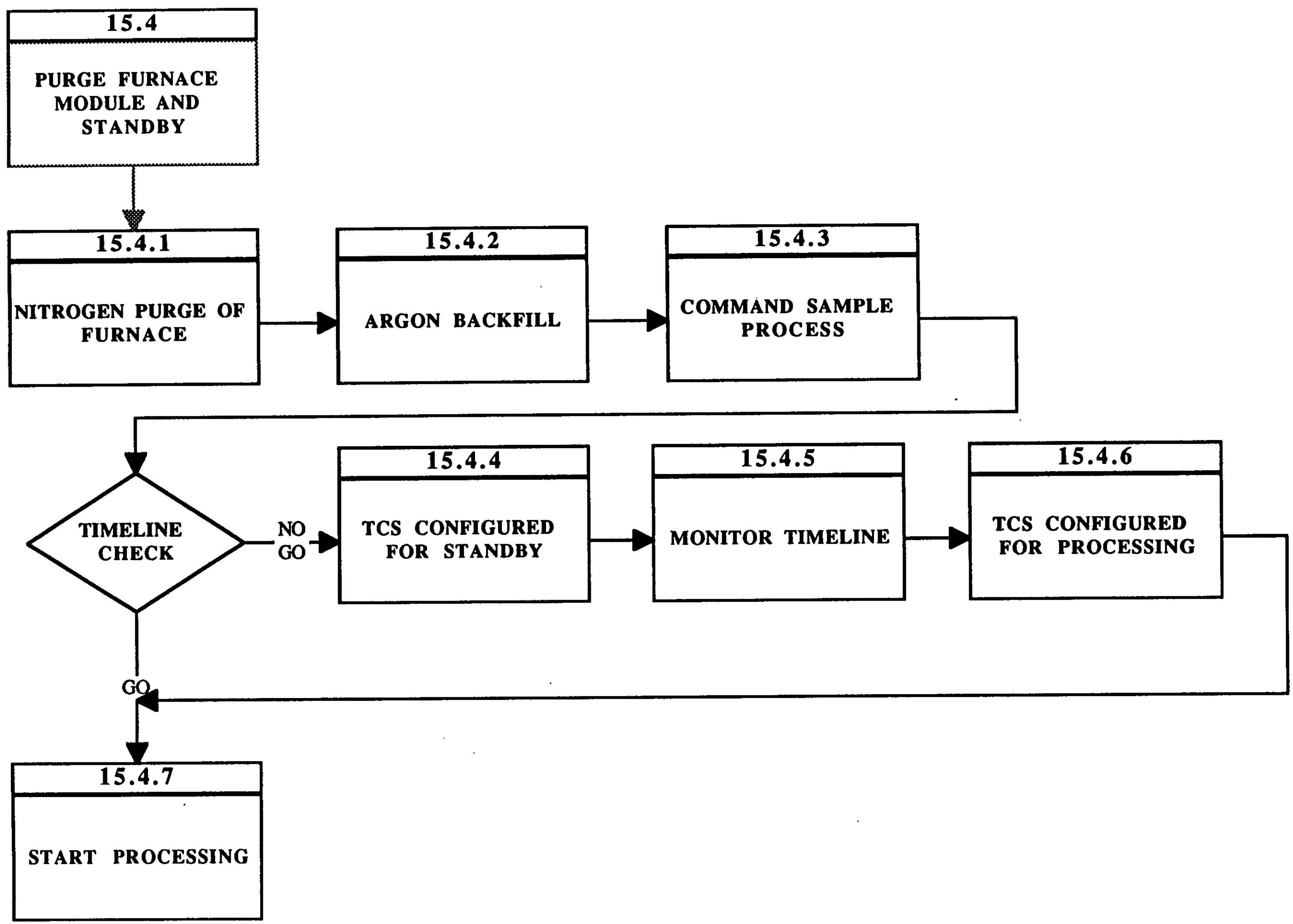


TABLE 5-1, FUNCTIONAL FLOW (Sheet 5 of 7)

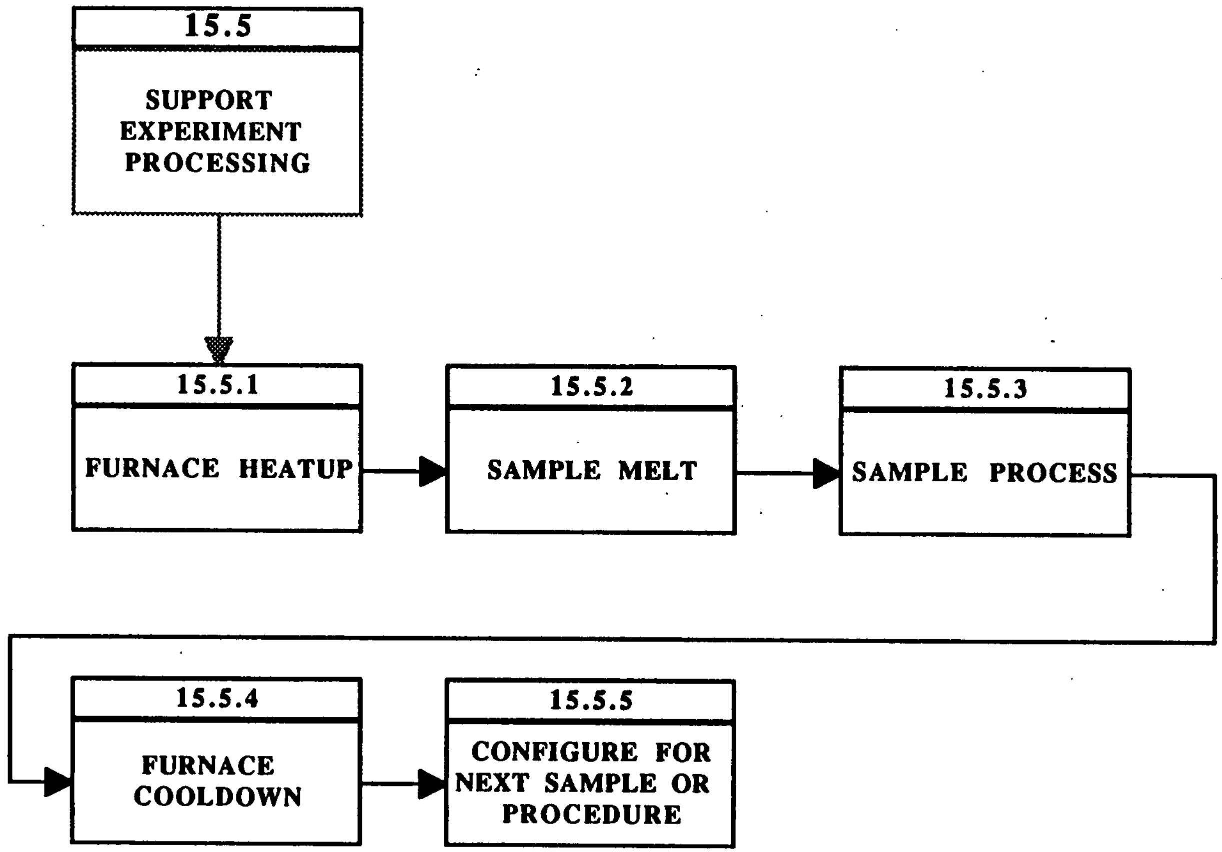


TABLE 5-1, FUNCTIONAL FLOW (Sheet 6 of 7)

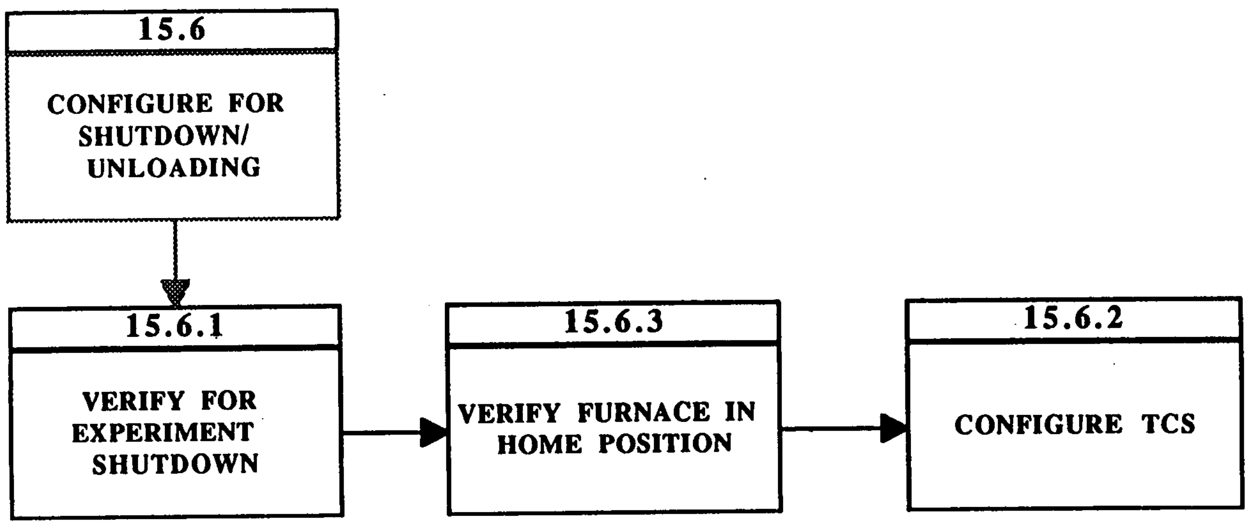


TABLE 5-1, FUNCTIONAL FLOW (Sheet 7 of 7)

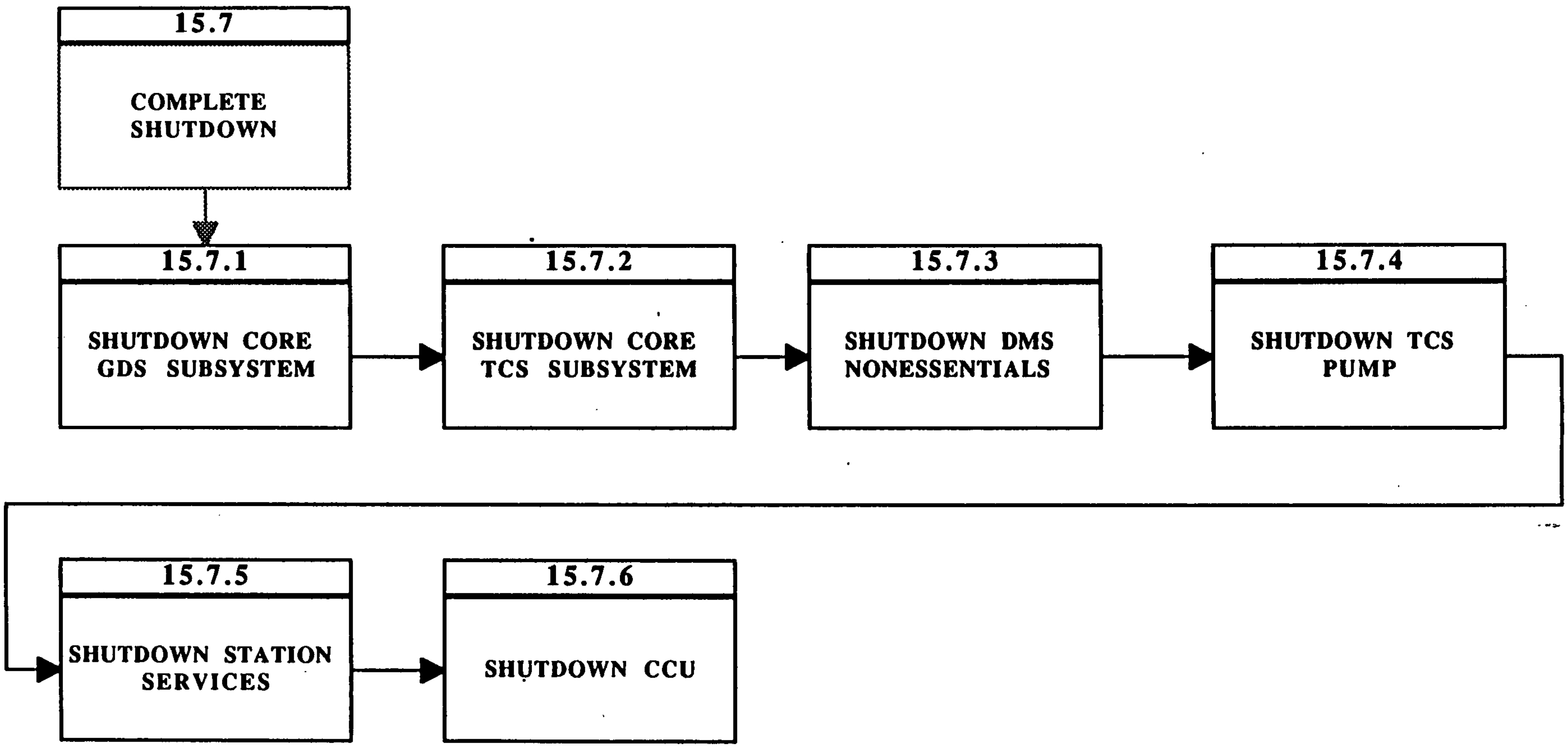


TABLE 5-2, DETAILED FUNCTIONAL FLOW OUTLINE

Task Description	Performed By	Comments
15.1.6 GDS TESTS	CCU	Cycle valves in core rack only
15.1.6.A Check gas lines		
15.1.6.B Pressure transducers		
15.1.6.C CMS check		
15.1.7 ACTIVATE AND TEST VIDEO AND HIGH RATE	CCU	
15.1.7.A activate camera signal		
15.1.7.B test video link		
15.1.7.Ctest high rate link		
15.1.8 CORE READINESS CHECK	CCU	
15.2 DISTRIBUTED CORE EQUIPMENT ACTIVATED		
15.2.1 CCU TURNS POWER ON TO RPCM	CCU	Closes switch to furnace RPCM
15.2.2 CCU TURNS ON FCU	CCU	
15.2.3 FCU CHECKOUT	FCU	
15.2.4 CCU TURNS ON FAU	CCU	
15.2.5 FAU CHECKOUT	FCU	
15.2.6 CCU CONFIGUREMENT AND VERIFICATION OF TCS	CCU	
15.2.6.A TCS LSV-03 switched to open position		
15.2.6.B Verify TCS LSV-03 position		
15.2.6.C TCS LSV-04 switched to open position		
15.2.6.D Verify TCS LSV-04 position		
15.2.6.E TCS LSV-02 switched to closed position		
15.2.6.F Verify TCS LSV-02 position		

TABLE 5-2, DETAILED FUNCTIONAL FLOW OUTLINE

Task Description	Performed By	Comments
15.2.7 FCU CHECKS GDS COMPONENTS	FCU	1 Furnace rack only
15.2.7.A. Pressure transducers		
15.2.7.B. Solenoid Valves		
15.2.7.C. Motor valves test		
15.2.7.D. CMS Sensors		
15.2.8 FURNACE SPECIFIC TESTS	FCU	
15.2.8.A Translation test		
15.2.8.B Video test		
15.3 FURNACE MANUAL SAMPLE EXCHANGE		
15.3.1 COMMAND MANUAL EXCHANGE	CREW/PES	
15.3.2 VENT /FILL FURNACE MODULE	CCU	
15.3.2.A Vent GN_2 to vacuum system if clean		
15.3.2.B Backfill furnace chamber with GN_2		
15.3.2.C Vent GN_2		
15.3.2.D Backfill furnace chamber with GN_2		
15.3.3 EQUALIZE FURNACE MODULE PRESSURE		CREW
15.3.3.A Argon and vent manual valves closed		
15.3.3.B Cabin air valve open		
15.3.4 PREP EQUIPMENT		
15.3.5 OPEN SIP		
15.3.6 INSERT SAMPLES		
15.3.6.A Insert samples		
15.3.6.B Visual verification of carousel movement		
15.3.7 CLOSE SIP		

TABLE 5-2, DETAILED FUNCTIONAL FLOW OUTLINE

Task Description	Performed By	Comments
15.3.8 OPEN VALVES	CREW	
15.3.8.A cabin air valve closed		
15.3.8.B vacuum vent manual valve opened		
15.3.8.C argon manual valve opened		
15.3.9 COMMAND MANUAL EXCHANGE OFF	CREW/PES	
15.3.10 PERFORM SEAL CHECK	CREW	
15.3.11 LOAD PROCESS LIST	CREW/PES/CCU	
15.3.11.A Confirm Telemetry Link w/ Ground Station		
15.3.11.B Load & Verify Experiment Software		
15.4 PURGE FURNACE MODULE		
15.4.1 GN_2 Purge Furnace	CCU	
15.4.1.A Backfill furnace with GN_2		
15.4.1.B Vent GN_2 to vacuum or waste gas		
15.4.1.C Backfill furnace with GN_2		
15.4.1.D Vent GN_2 to vacuum or waste gas		
15.4.3 COMMAND SAMPLE PROCESS	CCU	
15.4.3.A Check timeline and system warmup		GO continue to 15.5 NO GO continue to 15.4.4
15.4.4 TCS CONFIGURED FOR STANDBY		
15.4.5.A TCS LSV-01 verified in open position		
15.4.5.B TCS LSV-02 switched to open position		
15.4.5.C TCS LSV-03 switched to closed position		
15.4.5.D TCS LSV-04 switched to closed position -		FOR 2ND FURNACE ONLY
15.4.5 MONITOR TIMELINE		CONTINUE UPON SECURING RESOURCES AND TIMELINING

TABLE 5-2, DETAILED FUNCTIONAL FLOW OUTLINE

Task Description	Performed By	Comments
15.4.6 TCS CONFIGURED FOR PROCESSING	CCU	
15.4.7.A TCS LSV-01 verified in open position		
15.4.7.B TCS LSV-02 switched to closed position		
15.4.7.C TCS LSV-03 switched to open position		
15.4.7.D TCS LSV-04 switched to open position-		FOR 2ND FURNACE ONLY
15.5. SUPPORT EXPERIMENT OPERATIONS		
15.5.1. FURNACE HEAT UP	FCU	
14.5.1.A DMS indicates start		
14.5.1.B DMS monitors status		
15.5.2. SAMPLE MELT/SOAK	FCU	
14.5.2.ADMS monitors status		
15.5.3 SAMPLE PROCESS	FCU	
14.5.3.A DMS monitors status		
15.5.4 FURNACE COOLDOWN	FCU	
14.5.4.A DMS indicates cooldown		
14.5.4.B TCS configured for cooldown		
15.5.5 CAROUSEL EXCHANGE	FCU	Repeat 15.5.1-15.5.4 for preset no. of samples. After preset no. of samples go to 15.4. Continue to 15.5.6 upon completion of carousel
15.6.6 BACKFILL FURNACE	CCU	
15.6.6.A Backfill furnace chamber with GN2		
15.6.6.B Vent GN2		
15.6.17. EXPERIMENT DATA DUMP	CCU	Continuous throughout processing (Occurs only if necessary)

TABLE 5-2, DETAILED FUNCTIONAL FLOW OUTLINE

Task Description	Performed By	Comments
15.6 CONFIGURE FOR SAMPLE UNLOADING OR FURNACE SHUTDOWN		
15.6.1 VERIFY AND ACTIVATE FURNACE SHUTDOWN/UNLOADING	FCU	
15.6.2 CHECK FOR FURNACE IN HOME POSITION	FCU	
15.6.3 CONFIGURE FURNACE RACKS FOR SHUTDOWN	CCU	
15.7.3.A Power down furnace racks into standby		
15.7.3.B Secure Furnace Specific Services In The Core		
15.7 COMPLETE SSFF SHUTDOWN (CORE DEACTIVATION)		
15.7.1 VERIFY EXPERIMENT AND FURNACE SHUTDOWN	CCU	
15.7.2 SHUTDOWN CORE GDS SUBSYSTEMS	CCU	
15.7.3 SHUTDOWN CORE TCS SUBSYSTEMS	CCU	
15.7.3.A. TCS LSV-01 switched to closed position		
15.7.3.B. TCS LSV-02 switched to closed position		
15.7.3.C. TCS LSV-03 verified in closed position		
15.7.3.D. TCS LSV-04 verified in closed position		
15.7.3.E. Pump motor deactivated		
15.7.6 CORE CCU SHUTDOWN	CCU	
15.7.7 SHUTDOWN STATION SERVICES	CCU	
15.7.7.A Inform SSF that cooling supply is no longer needed.		
15.7.7.B Inform SSF that avionics air supply is no longer needed.		
15.7.7.C Turn off manual valves to services		

TABLE 5-3. EVENT RELATED AND COMPONENT LIST

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.1.1	CCU and CMCU Act	15.1.1	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors
15.1.2	SSFF to Ground Link	15.1.2	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors
15.1.3	Test CMCU	15.1.3	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors
15.1.4	Configure and Test TCS in Core Rack	15.1.4	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers
15.1. 5	Test CPC	15.1. 5	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Core Power Conditioners

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.1.6	GDS Test	15.1.6	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Latching Solenoid Valves Contamination Monitor
15.1.7	Activate Camera And Videolink (IF APPLICABLE)	15.1.7	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit
15.1.8	Core Readiness Check	15.1.8	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.2.1	CCU powers RPCM/DCMU	15.2.1	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit
15.2.2	CCU powers FCU	15.2.2	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit
15.2.3	FCU Checkout	15.2.3	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit
15.2.4	FAU powered	15.2.4	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.2.4 cont.	FAU powered	15.2.4 cont.	Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.2.5	FMCU Checkout	15.2.5	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.2.6	Configured and Test TCS in Furnace Rack	15.2.6	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.2.7	GDS test	15.2.7	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.2.8	Furnace Specific Tests	15.2.8	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.3.1	Command Manual Sample Exchange	15.3.1	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters .Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.3.2	Vent/Fill Furnace Module 1	15.3.2	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.3.3	Equalize Furnace Module 1 Pressure	15.3.3	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit Manual Valve
15.3.4	Prep Equipment	15.3.4	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.3.4 cont.	Prep Equipment	15.3.4 cont.	RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.3.5	Open SIP	15.3.5	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.3.6	Insert Samples	15.3.6	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.3.7	Close SIP	15.3.7	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.3.7 cont.	Close SIP	15.3.7 cont.	Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.3.8	Open Valves	15.3.8	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit Manual Valves
15.3.9	Command Man. Sample Exchange Off	15.3.9	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.3.10	Perform Seal Check	15.3.10	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.3.11	Load Process List	15.3.11	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.4.1	GN2 Purge Furnace	15.4.1	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.4.2	Argon Backfill	15.4.2	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.4.3	Command Sample Process	15.4.3	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.4.4	TCS Configured for Standby	15.4.4	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.4.4 cont.	TCS Configured for Standby	15.4.4 cont.	Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.4.5	Monitor Timeline	15.4.5	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS Essentials Power Supply Voltage and Current Sensors Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit
15.4.6	TCS configured for Processing	15.4.5	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.5.1-15.5.4	Sample Process	15.5.1-15.5.4	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit Furnace Module 1

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.6.1	Verify for experiment shutdown	15.6.1	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit Furnace Module 1
15.6.2	Furnace In HOME position	15.6.2	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit Furnace Module 1
15.6.3	Configure TCS	15.6.3	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit Furnace Control Unit Furnace Actuator Unit Furnace Module 1

TABLE 5-3. EVENT RELATED AND COMPONENT LISTS (Continued)

FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.7.1	Shutdown GDS Subsystems	15.7.1	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit
15.7.2	Shutdown TCS Subsystems	15.7. 2	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit Distributed Core Monitoring Unit
15.7.3	DMS Nonessentials Shutdown	15.7.3	Core Control Unit Removable Hard Drive CDROM/WORM Drive High Density Recorder Core Monitor Control Unit Crew Interface CPCS RPCM Essentials Power Supply Voltage and Current Sensors Shutoff Valves Pump Package Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers Video Processor Unit
15.7. 4	TCS Pump Shutdown	15.7.4	Core Control Unit Core Monitor Control Unit RPCM Essentials Power Supply Voltage and Current Sensors Flow Meters Flow Control Valves Temperature Sensors Pressure Transducers

TABLE 5-3. EVENT RELATED AND COMPONENT LIST (Continued)

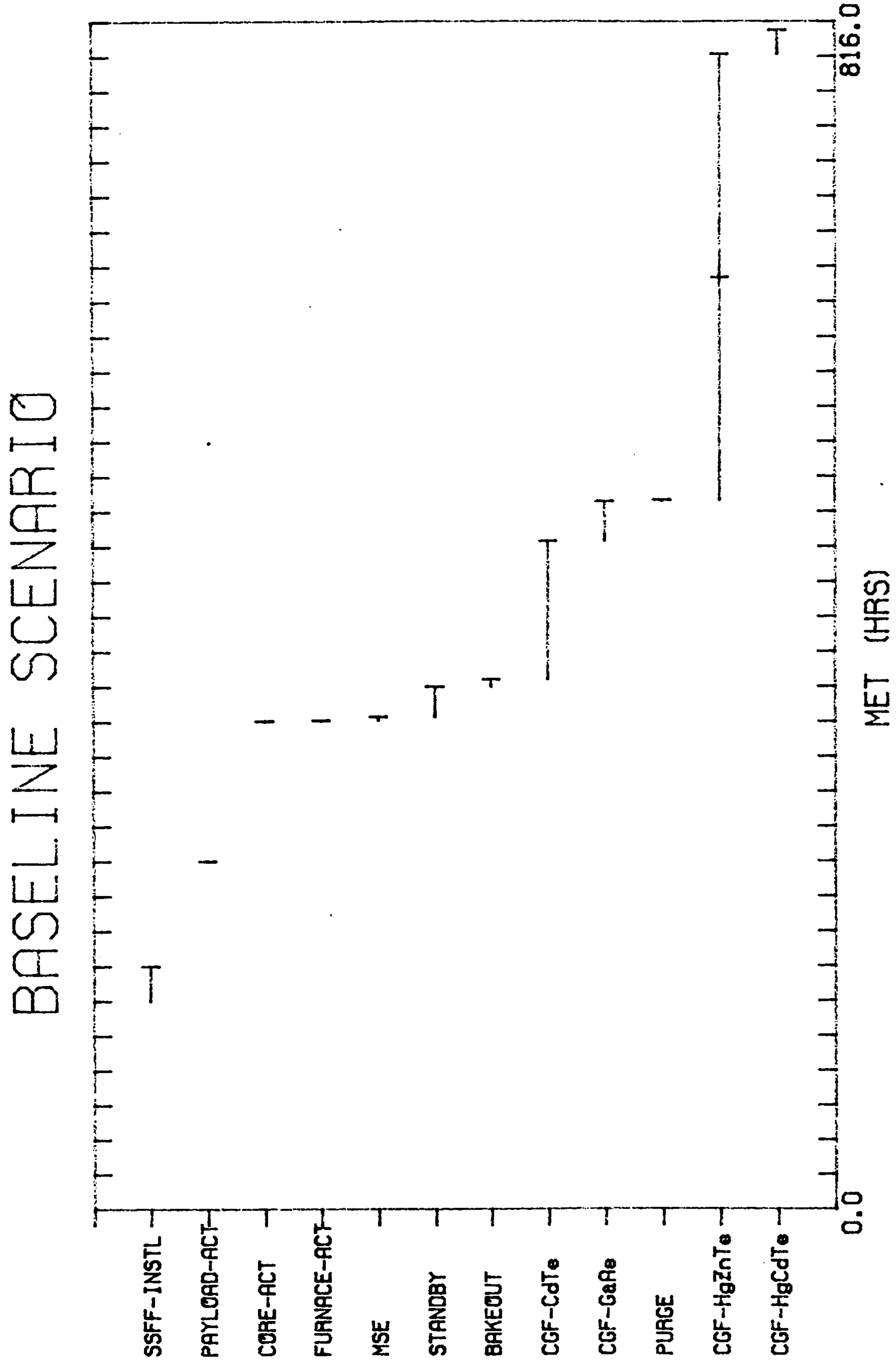
FUNCTIONAL OBJECTIVE		EQUIPMENT REQUIRED	
NUMBER	TITLE	NUMBER	ITEM
15.7.5	Request Station Services Shutdown	15.7.5	Core Control Unit Core Monitor Control Unit Essentials Power Supply Voltage and Current Sensors
15.7.6	CCU Shutdown	15.7.6	

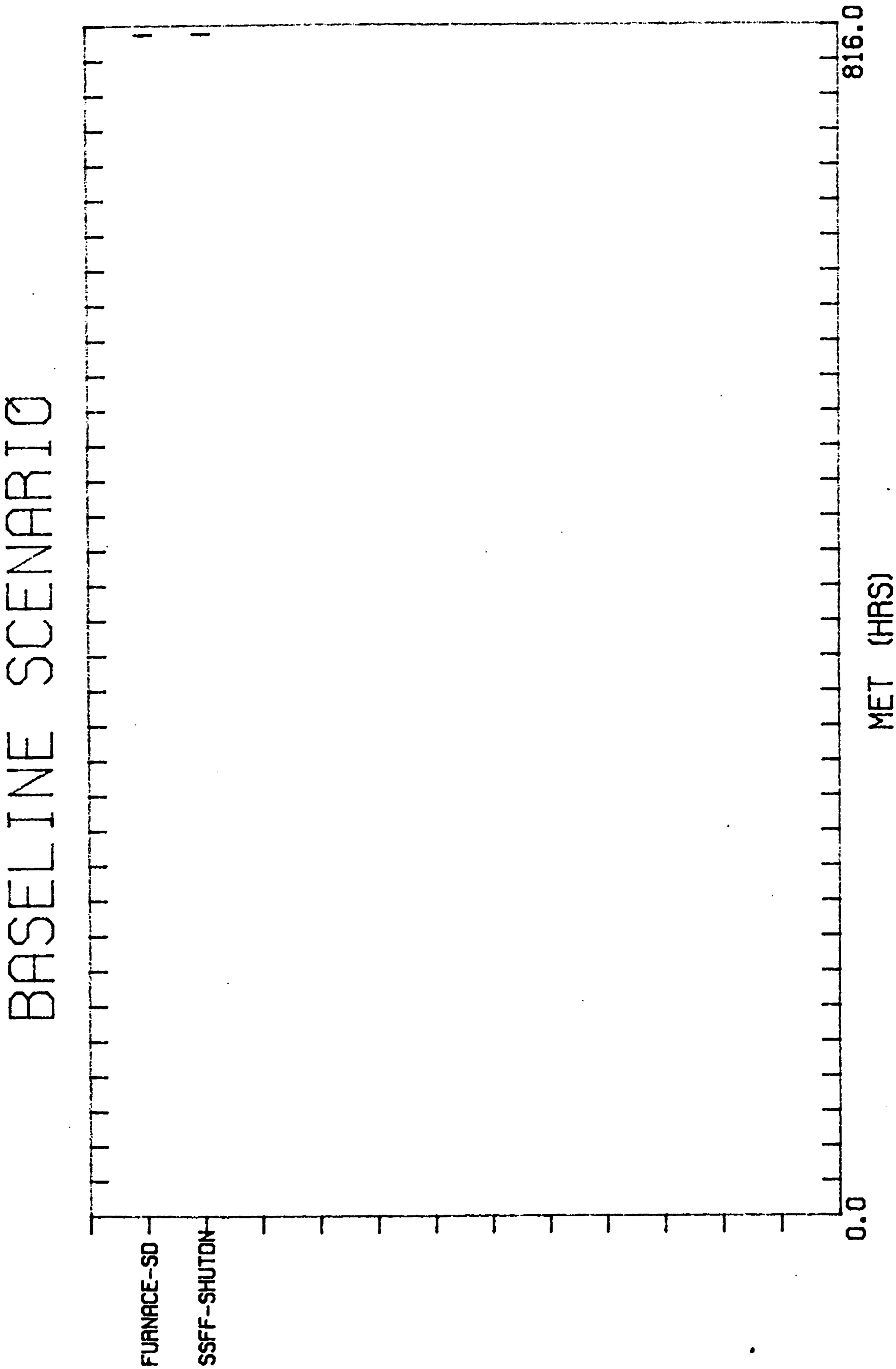
TABLE 5-4, RESOURCE AND EVENT RELATED LIST

Task Identity #	Task Description	Peak Power Req'd	Thermal(air)	Thermal(liquid)	Data Generated
15.0.1	Manual valves	0.0	0.0	0.0	0.0
15.0.2	SSF specific services	0.0	0.0	0.0	0.0
15.1.1	Activate CCU andCMCU	1000.8	114.0	886.8	16.0
15.1.2	SSF to Ground Link	1000.8	114.0	886.8	32.0
15.1.3	Test CMCU	1000.8	114.0	886.8	16.0
15.1.4	Configure and test TCS	1147.9	121.4	1026.5	16.0
15.1.5	Test CPC	1463.7	137.2	1326.5	100.0
15.1.6	GDS test in core	1305.8	129.3	1176.5	16.0
15.2.1	CCU powers RPCM	1322.0	263.5	1058.5	16.0
15.2.2	CCU powers FCU	1762.0	285.5	1476.5	16.0
15.2.3	FCU Checkout	1762.0	285.5	1476.5	16.0
15.2.4	FAU Powered	2098.8	302.3	1796.5	16.0
15.2.5	FAU Checkout	2098.8	302.3	1796.5	16.0
15.2.6	CCU Configurment of TCS	2113.6	303.1	1810.5	16.0
15.2.7	Checkout GDS	1816.5	304.4	1816.5	16.0
15.2.8	Furnace Specific Test	1816.5	332.2	1816.5	16.0
15.3.1	Command Sample Exchange	2148.7	332.2	1816.5	16.0
15.3.2	Vent /FillFurnace Module	2148.7	332.2	1816.5	16.0
15.3.3	Equalize Pressure	2148.7	332.2	1816.5	16.0
15.3.4	Prep Equipment	2148.7	332.2	1816.5	16.
15.3.5	Open SIP	2148.7	332.2	1816.5	16.0
15.3.6	Insert Samples	2148.7	332.2	1816.5	16.0
15.3.7	Close SIP	2148.7	332.2	1816.5	16.0
15.3.8	Open Valves	2148.7	332.2	1816.5	16.0
15.3.9	Command Man. Exchange Off	2148.7	332.2	1816.5	16.0
15.3.10	Perform Seal Test	2148.7	332.2	1816.5	16.0
15.3.11	Load Process List	2148.7	332.2	1816.5	16.0
15.4.1	GN2 Purge Furnace	2152.7	346.2	1816.5	16.0
15.4.2	Argon Backfill	2152.7	346.2	1816.5	16.0
15.4.3	Command Sample Process	2133.6	317.1	1816.5	16.0
15.4.4	TCS Configured	2163.9	347.4	1816.5	16.0
15.5.1	Furnace Heatup	SAMPLE DEPENDENT SEE SPECIFIC SCENARIO			
15.5.2	SampleMelt/Soak	SAMPLE DEPENDENT SEE SPECIFIC SCENARIO			
15.5.3	Sample Process	SAMPLE DEPENDENT SEE SPECIFIC SCENARIO			
15.5.4	Cool Sample	SAMPLE DEPENDENT SEE SPECIFIC SCENARIO			
15.6.1	Check for Home Position	1147.9	121.4	1026.5	16.0
15.6.2	Furnace specific Test	1147.9	121.4	1026.5	100.0
15.7.1	Verify Experiment Shutdown	1147.9	121.4	1026.5	100.0
15.7.2	Shutdown GDS core subsystems	1147.9	121.4	1026.5	16.0
15.7.3	Shutdown DMS Nonessentials	561.2	32.1	529.2	16.0
15.7.4	Shutdown TCS core subsystems	321.5	20.1	301.4	16.0
15.7.5	Shutdown Power and CCU	0.0	0.0	0.0	16.0

TABLE 5-5. NORMAL SCENARIO CREW ACTIVITY LIST

14.6	**INSTALLATION OF RACKS** **(not required for every mission)**
15.0	**MANUAL CONFIGURATION**
15.0.1-15.0.2	OPEN VALVES
15.3	**MANUAL SAMPLE EXCHANGE**
15.3.1	COMMAND MANUAL SAMPLE EXCHANGE
15.3.3	EQUALIZE FURNACE MODULE PRESSURE
15.3.4	PREP EQUIPMENT
15.3.5	OPEN SIP
15.3.6	INSERT SAMPLES
15.3.7	CLOSE SIP
15.3.8	OPEN VALVES
15.3.9	COMMAND MANUAL EXCHANGE OFF
15.3.10	PERFORM SEAL TEST
15.3.11	LOAD PROCESS LIST


BASELINE SCENARIO
SSFF-INSTL
PAYLOAD-ACT
CORE-ACT
FURNACE-ACT
MSE
STANDBY
BAKEOUT
CGF-CdTe
CGF-GaAs
PURGE
CGF-HgZnTe
CGF-HgCdTe
0.0
816.0
MET (HRS)



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APPENDIX A

INTRODUCTION

GENERAL

The results of the engineering analysis effort to integrate approximately 15 scenarios will be provided in this appendix. The WBS 1.4.3 calls for approximately 15 scenarios covering man-tended and permanently manned operations. The appendix contains a description and an overview for each scenario generated. A mission timeline, power timeline, data generation timeline, thermal rejection timeline, crew activity timeline and a summary of data follows each overview.

PURPOSE

The purpose of this document is to provide the data and timelines for power circuit demands, crew activities, data generation, and thermal demands for 15 generated scenarios

APPLICABLE DOCUMENTS

WP 01 D683-10496-1	Orbital Operations Requirements Analysis Data DR OP-16
WP 01 D683-10495-1	Systems Operations Scenarios DR OP-17
MSFC JA- 1437	Crystal Growth Furnace Payload Operating Procedure
320RPT0008	SSFF Subsystems Concept Reports Science Capabilities Requirements Document

BASELINE SCENARIO

BASELINE SCENARIO DESCRIPTION

Scenario #1 is used as a baseline for SSFF operations. The first sample is a characterization sample for the furnace. The remaining five samples are HgCdTe, HgZnTe, GaAs, CdTe and HgZnTe. HgZnTe is repeated to demonstrate typical SSFF operation with a six sample carousel. The processing time for completion of all samples does not require the entire 90 day mission.

BASELINE SCENARIO OVERVIEW

The operation of the SSFF in this scenario is as follows: Installation of the core rack and Furnace Module #1 occur on Utilization Flight TBD. The checkout of all hoses, lines, and equipment will be performed by the crew during Installation. Upon completion of the Installation stage, activation will occur. Activation occurs with the core equipment and distributed equipment respectively. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within the furnace rack. The Furnace Module is included in this activation step. After all the equipment is powered and allowed to warm-up, the SSFF reaches a standby mode. This Standby mode is when power consumption for subsystems is at normal operating amounts and the Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

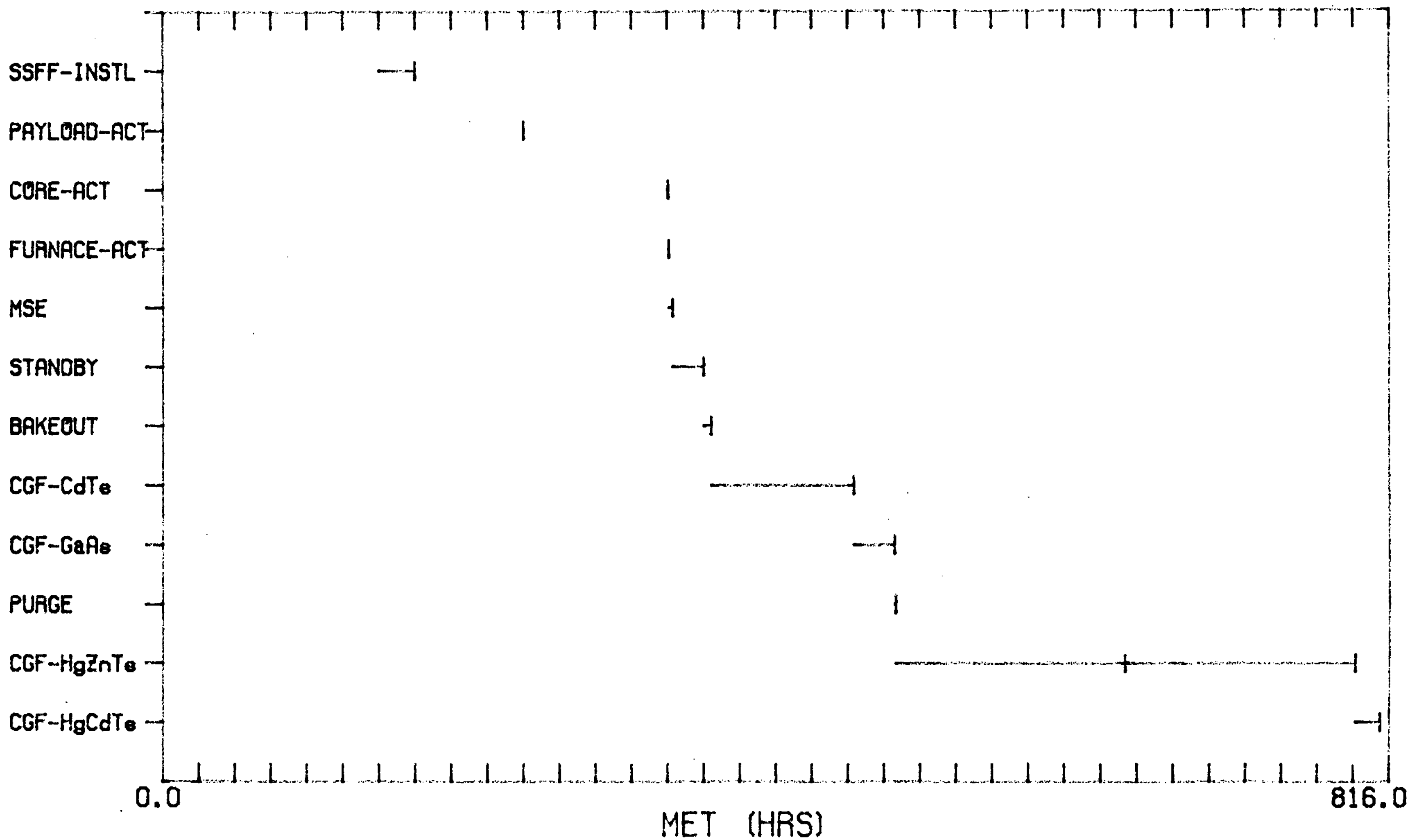
Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the Furnace Module is in a safe condition for crew interaction. After the samples are loaded in the Furnace Module, it is purged with Nitrogen. The furnace is then configured for a processing of samples. The configurement of the furnace depends on what sample is being processed. The furnace is vented of the nitrogen and filled with a processing gas. Argon is the processing gas in this scenario. At this point during Man-Tended Configuration the furnaces will remain at Standby mode until the crew leaves the SSF. Processing will occur upon crew departure from SSF to minimize vibrational disturbances. The time for completion of the activities listed above occur within the first 15 days of the 90 day mission. This will be the only time crew will be available for checkout of proper operation of systems and correction of any problems.

Upon crew departure a signal from the Core Control Unit (CCU) will allow for the Furnace Module to power up and start the processing cycle. The first sample to be processed is a calibration and bakeout sample. This sample calibrates the furnace at a predetermined time limit and proceeds with a bakeout of moisture for approximately 5 hours. Processing of two samples,\ CdTe and GaAs, occur next. Upon completion of processing a single sample, the carousel within

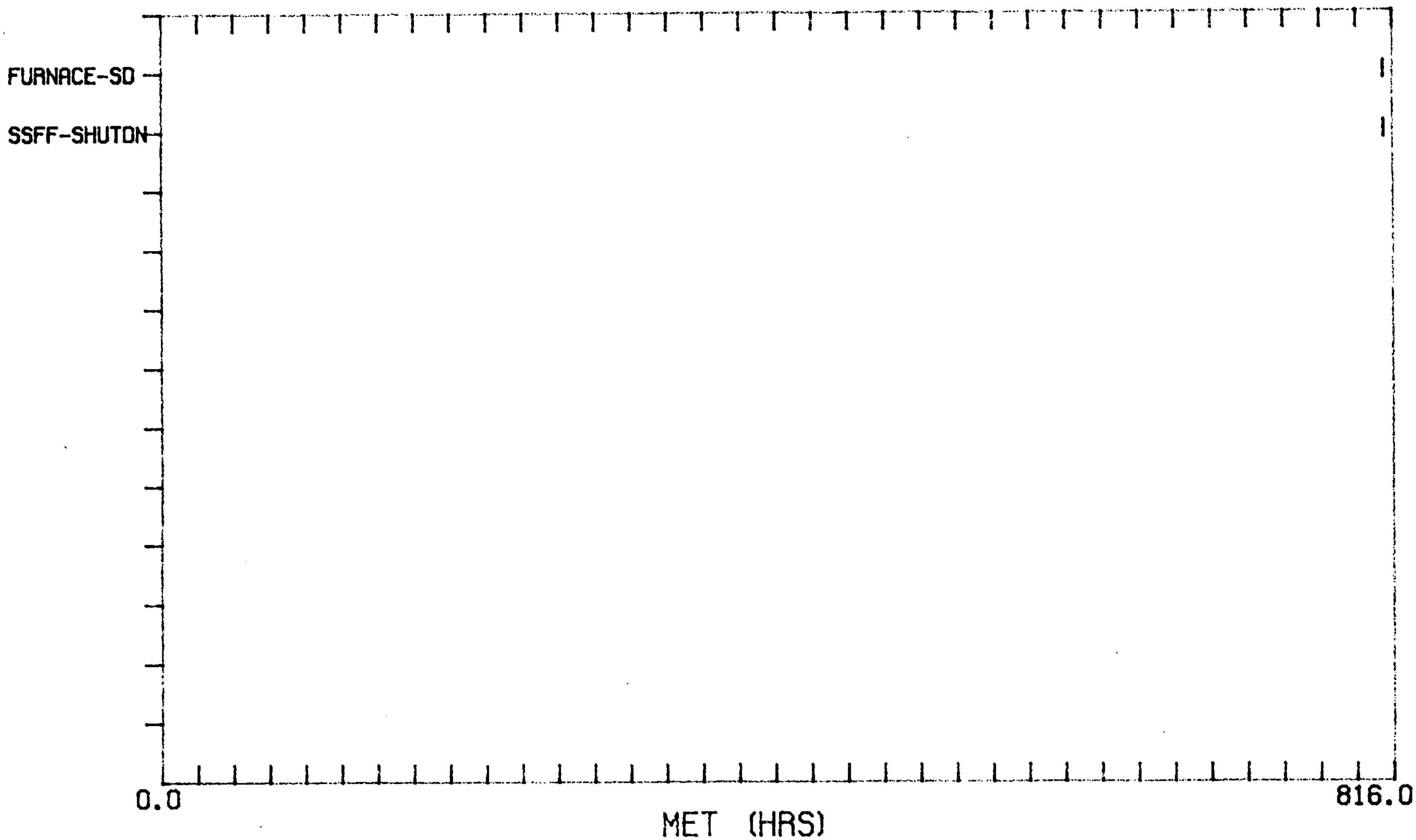
the furnace module will deliver a subsequent sample to be processed. Purging of the furnace with fresh processing gas occurs after the first three samples in this scenario. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). Two samples of HgZnTe and a sample of HgCdTe are processed after a new supply of argon is contained within the furnace module. Upon completion of the entire carousel of samples the furnace is returned to a standby mode. From the standby mode complete shutdown can occur.

Shutdown occurs through a process of: reconfiguration of the SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration is required to vent the furnace of processing gas, configure the TCS into the core rack, and check that the furnace is in the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

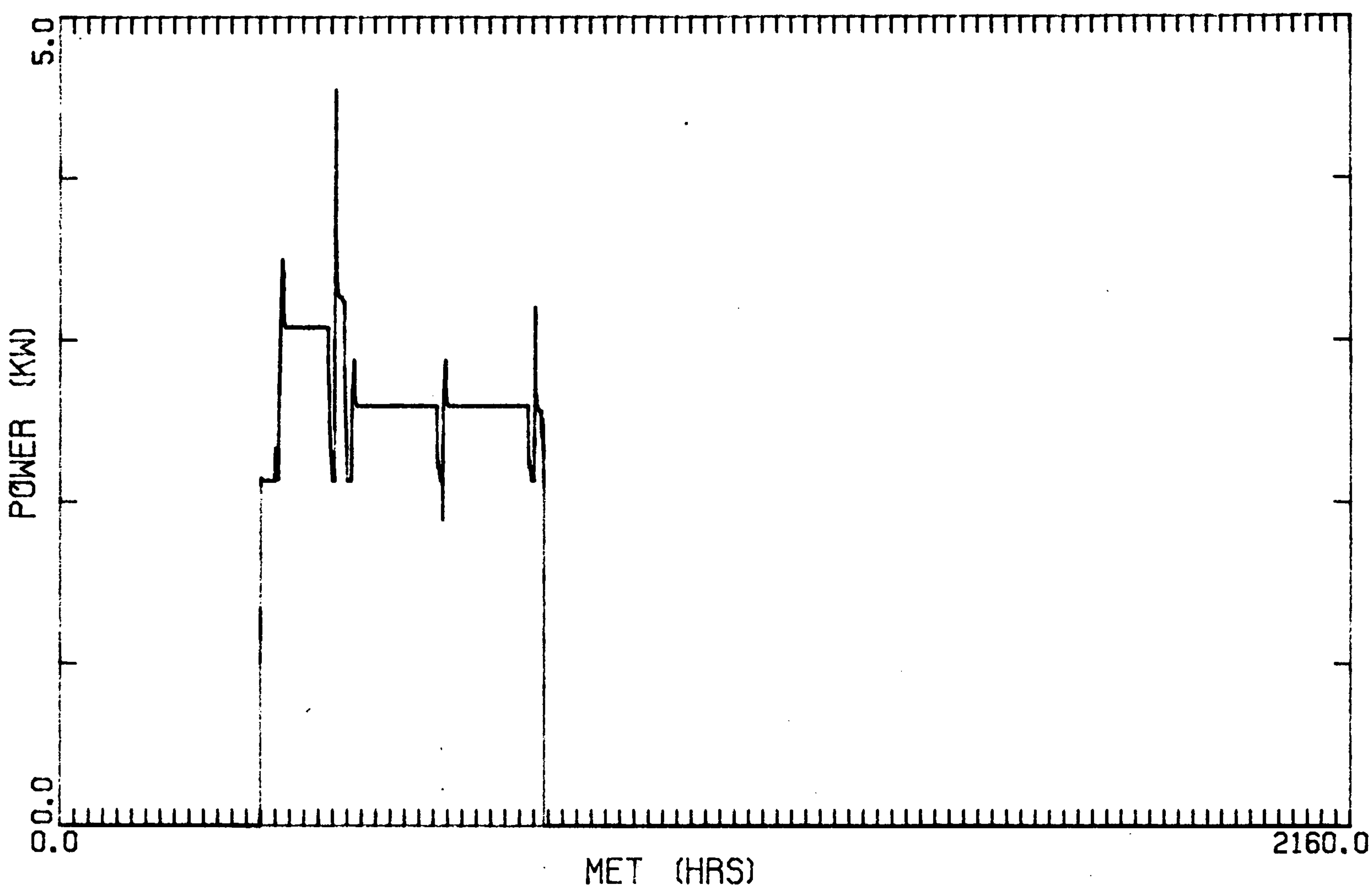
BASELINE SCENARIO



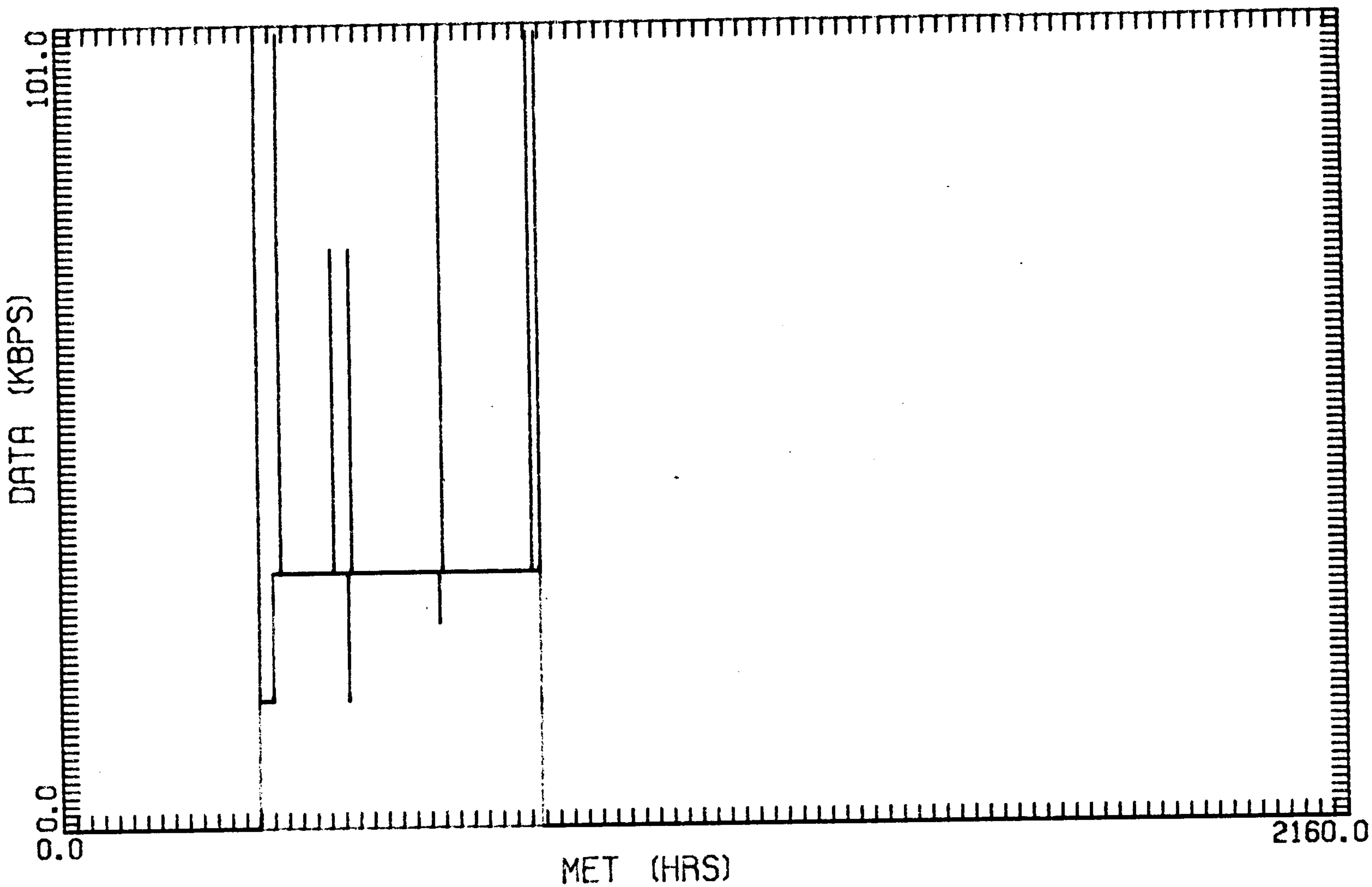
BASELINE SCENARIO



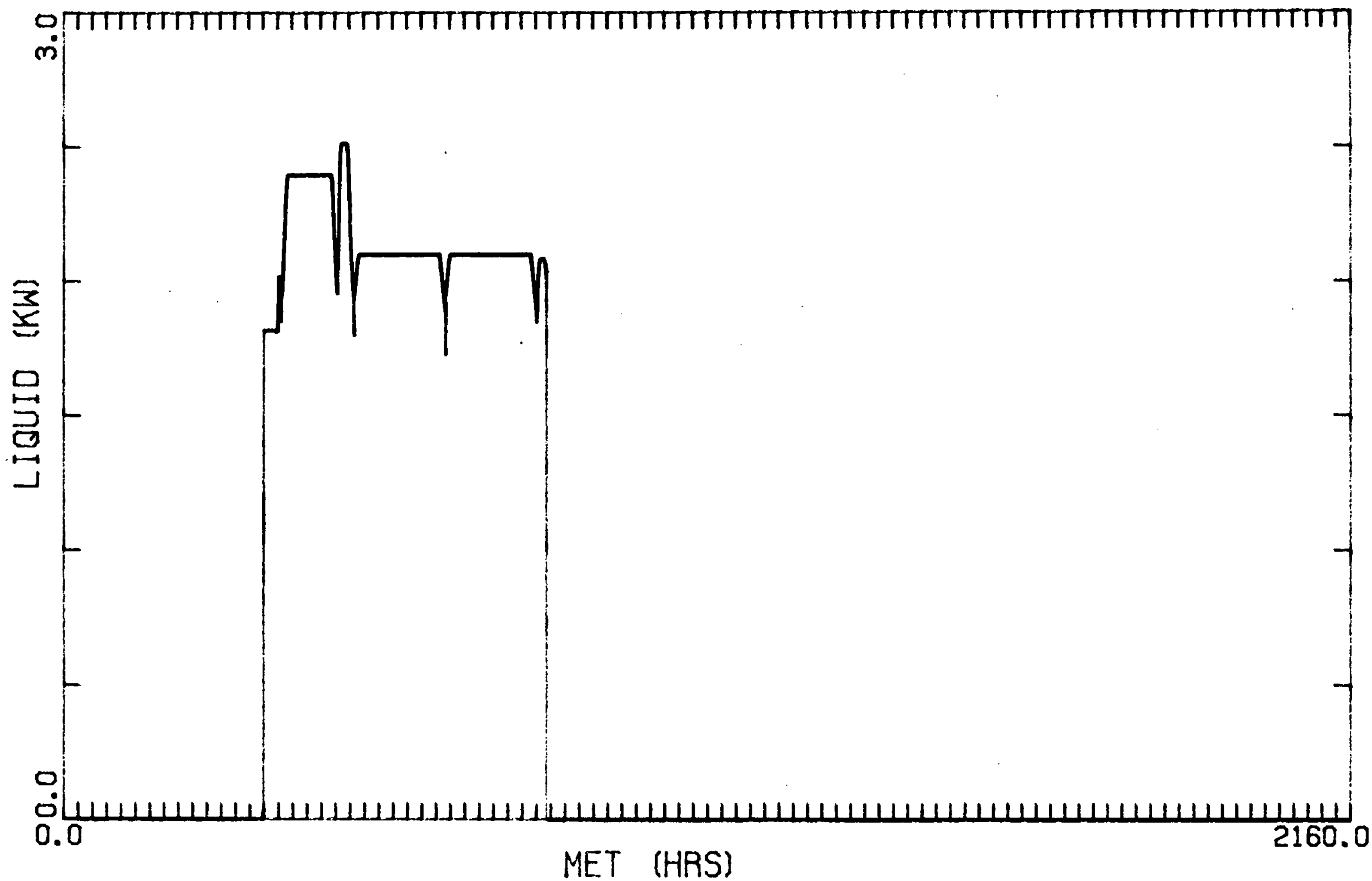
BASELINE SCENARIØ



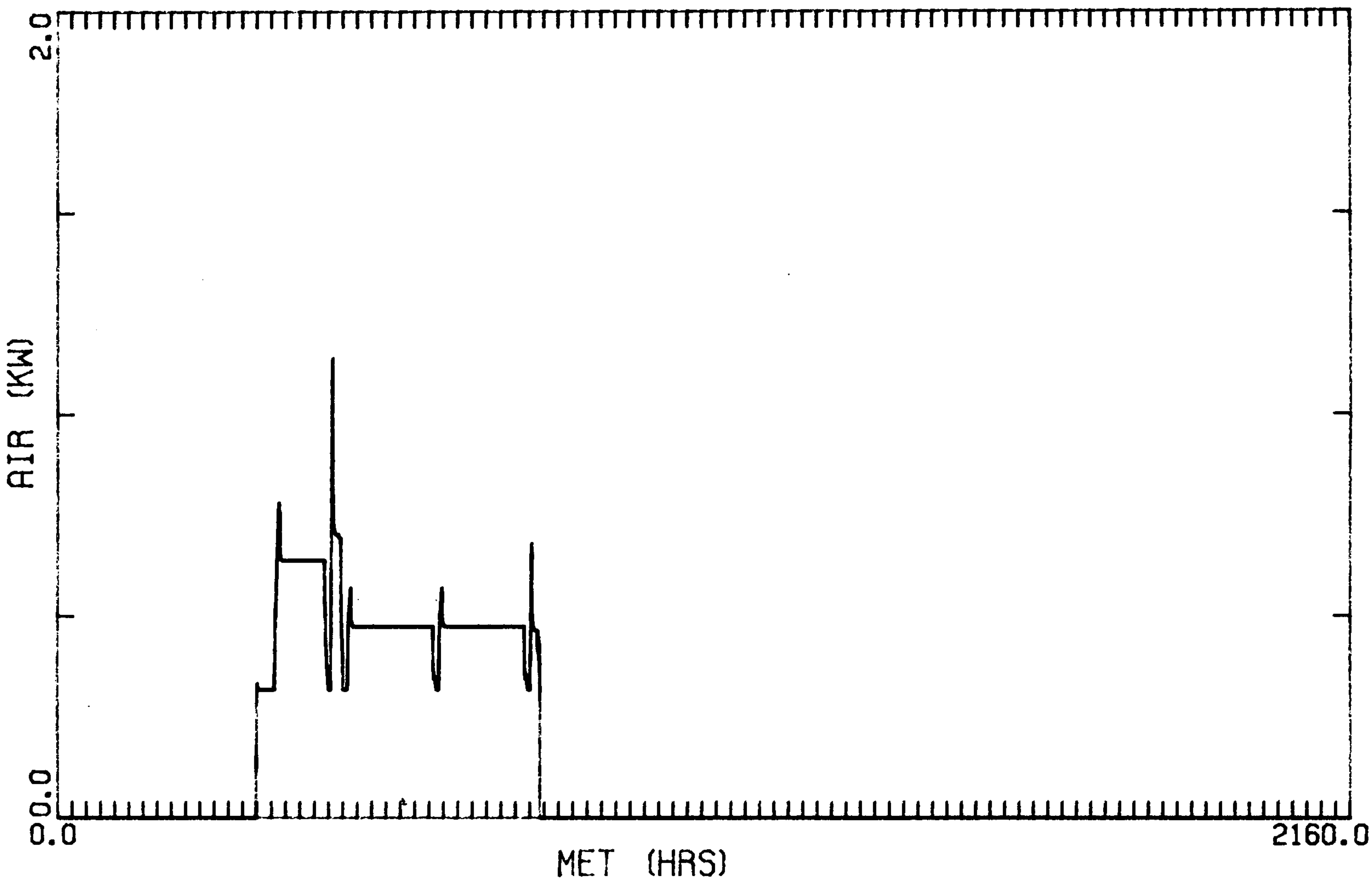
BASELINE SCENARIØ

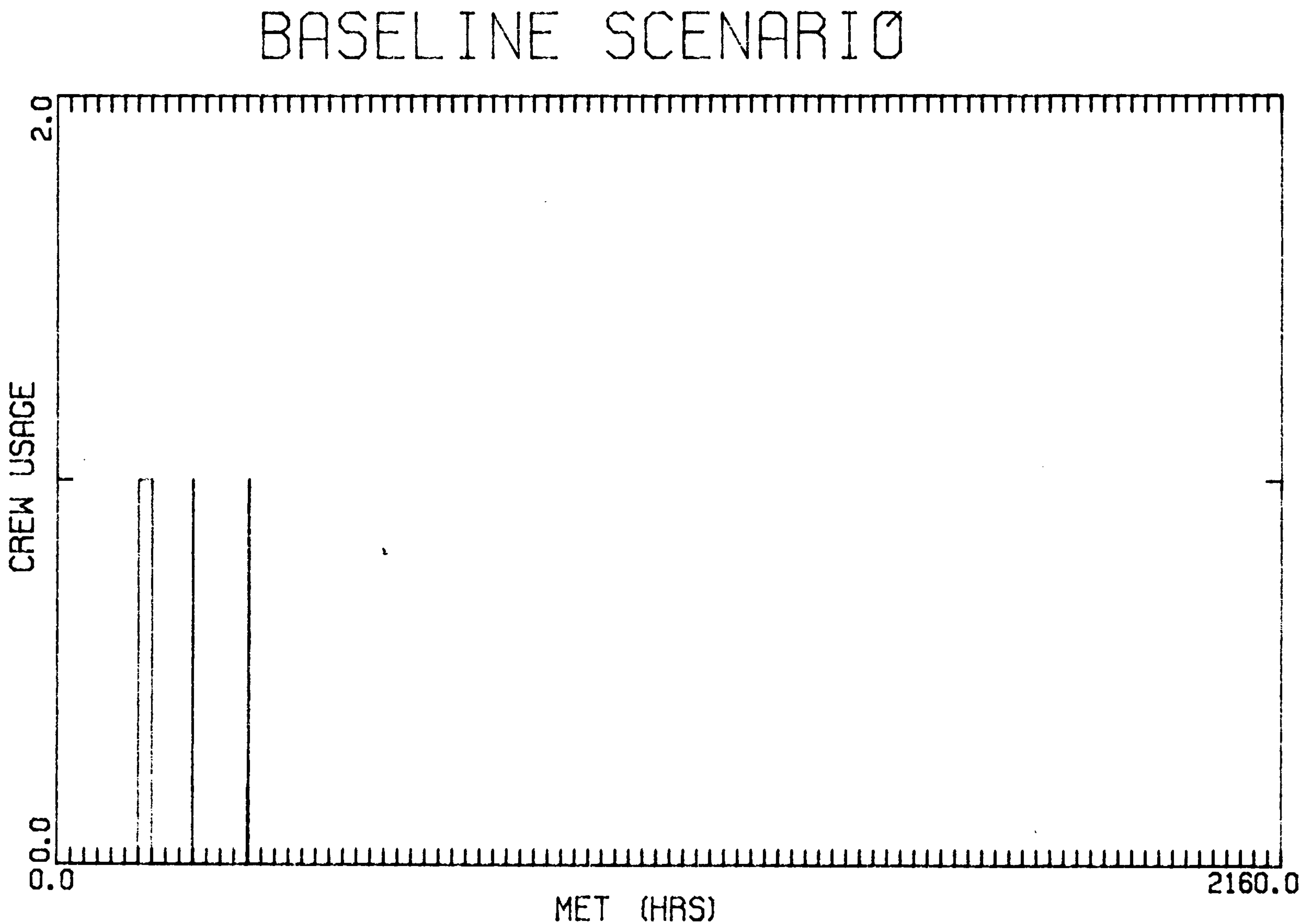


BASELINE SCENARIO



BASELINE SCENARIØ




BASELINE SCENARIO
CREW USAGE
2.0
0.0
0.0
2160.0
MET (HRS)

BASELINE SCENARIO

MODEL SSFF-INSTL	INSERTED FROM	144.00 HRS	TO	168.00 HRS	
MODEL PAYLOAD-ACT	INSERTED FROM	240.00 HRS	TO	240.18 HRS	
MODEL CORE-ACT	INSERTED FROM	336.00 HRS	TO	336.50 HRS	
MODEL FURNACE-ACT	INSERTED FROM	336.50 HRS	TO	336.95 HRS	
MODEL MSE	INSERTED FROM	336.95 HRS	TO	339.55 HRS	
MODEL STANDBY	INSERTED FROM	339.55 HRS	TO	360.10 HRS	
MODEL BAKEOUT	INSERTED FROM	360.10 HRS	TO	365.10 HRS	
MODEL CGF-CdTe	INSERTED FROM	365.10 HRS	TO	460.00 HRS	
MODEL CGF-GaAs	INSERTED FROM	460.00 HRS	TO	487.20 HRS	
MODEL PURGE	INSERTED FROM	487.20 HRS	TO	487.97 HRS	
MODEL CGF-HgZnTe	INSERTED FROM	487.97 HRS	TO	640.67 HRS	
MODEL CGF-HgZnTe	INSERTED FROM	640.68 HRS	TO	793.38 HRS	
MODEL CGF-HgCdTe	INSERTED FROM	793.38 HRS	TO	809.88 HRS	
MODEL FURNACE-SD	INSERTED FROM	809.88 HRS	TO	810.03 HRS	
MODEL SSFF-SHUTDN	INSERTED FROM	810.03 HRS	TO	810.27 HRS	

**** MAXIMUM RES1-POWER 4.559 KW
**** MAXIMUM RES2-DATA GENERATION 100.000 KBPS

**** TOTAL ENERGY RES1= 1255.69 KWH
**** TOTAL ENERGY RES2= 14823.93 KBPSH = 6670768.5 KBytes DATA VOLUME

GROUP 1 ENERGY RES1 = 1255.69	RES2 = 14823.93	CREW TIME (M-Hr) =	26.25
GROUP 2 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 3 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 4 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 5 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 6 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 7 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 8 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 9 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 10 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 11 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 12 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 13 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 14 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 15 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 16 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 17 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 18 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 19 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 20 ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 2.6476 KW

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
SSFF-INSTL	1	1	100.00000000%
PAYLOAD-ACT	1	1	100.00000000%
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE	1	1	100.00000000%
STANDBY	1	1	100.00000000%

BAKEOUT	1	1	100.00000000%
CGF-CdTe	1	1	100.00000000%
CGF-GaAs	1	1	100.00000000%
PURGE	1	1	100.00000000%
CGF-HgZnTe	2	2	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
FURNACE-SD	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

BASELINE SCENARIO

**** MAXIMUM RES1-LIQUID 2.514 KW
**** MAXIMUM RES2-AIR 1.141 KW

**** TOTAL ENERGY RES1= 1013.47 KWH
**** TOTAL ENERGY RES2= 232.96 KWH

GROUP 1	ENERGY RES1 =	1013.47	RES2 =	232.96	CREW TIME	(M-Hr) =	0.00
GROUP 2	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 3	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP 20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00

EXTENDED BASELINE SCENARIO DESCRIPTION

Scenario #2 demonstrates a typical mission under normal SSFF operations. The samples are again HgCdTe, HgZnTe, CdTe, and a characterization sample. HgZnTe and CdTe are again repeated. However, the run time for one sample of HgZnTe is lengthened to complete the processing of a 12-15 cm sample. This time increase accounts for 42 additional days in processing time. This scenario will fill approximately 80 days of the 90 day mission cycle. A full 90 day mission cycle could be occupied by extending the processing the time for this or other samples.

EXTENDED BASELINE SCENARIO OVERVIEW

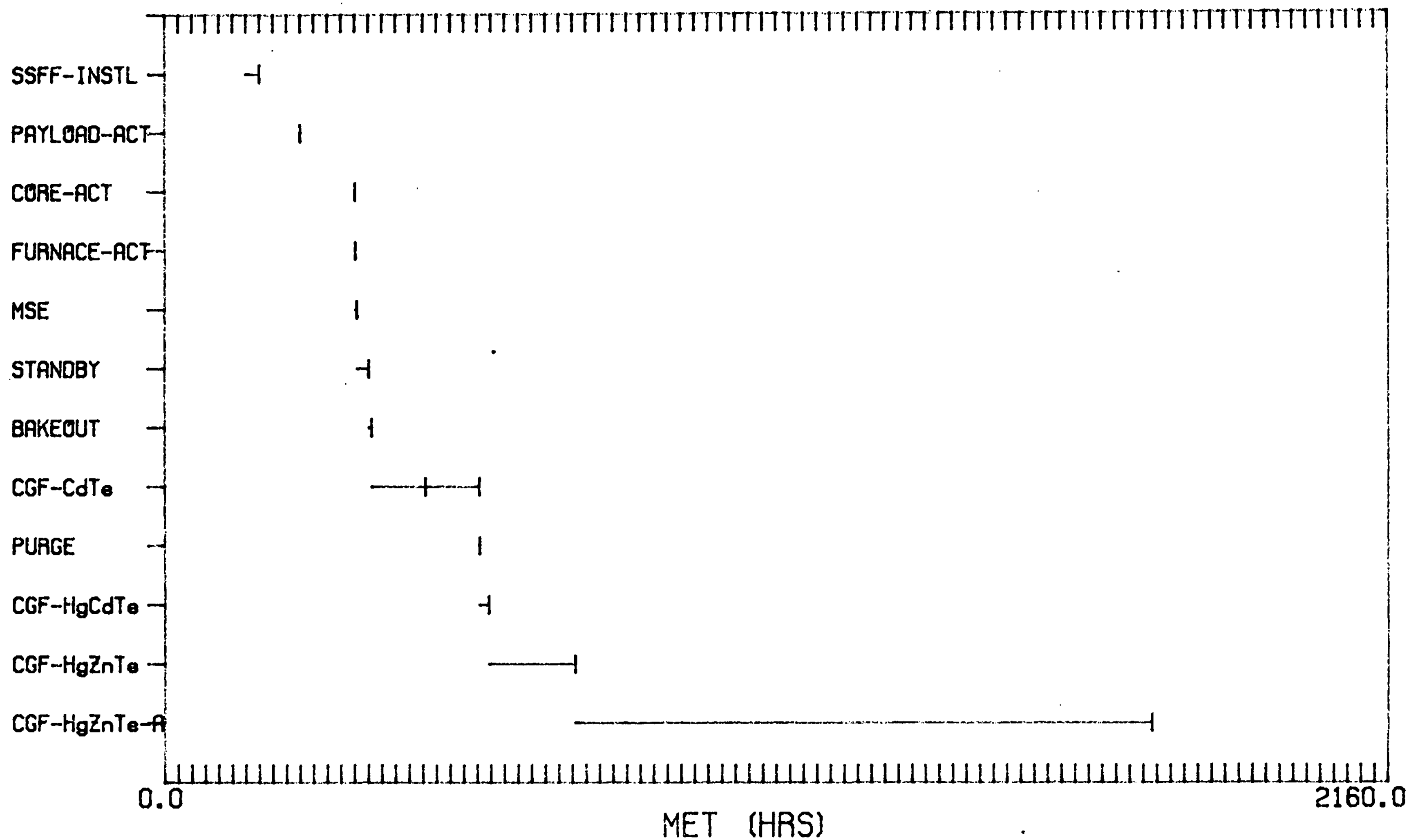
The operation of this SSFF scenario is as follows: Installation of the core rack and Furnace Module #1 occur first. Upon completion and checkout of equipment, activation will follow. Activation of the core equipment and distributed equipment occur respectively. The SSFF then reaches a standby condition where power consumption for subsystems are at normal operating amounts and the furnace module power consumption is at zero. The SSFF will fall back to these levels at several times during the 90 day mission. Samples are then loaded by the crew. Samples are loaded while in a Manual Sample Exchange mode. This mode allows the SSFF subsystems to remain in standby while the furnace module is in safe condition for crew interaction. The furnace is purged and filled with argon for processing of samples. At this point during Man-Tended Configuration the furnaces will remain at Standby until the crew leaves the SSF. Processing will occur upon crew departure from SSF to minimize unnecessary vibrational disturbances. The time for completion of the activities listed above occur within the first 15 days of the 90 day mission. This allows for crew checkout of all systems and correction of any problems if necessary .

Upon crew departure a signal will occur for the Furnace Module to power up and start the processing cycle. The first sample to be processed is a calibration and bakeout sample This calibrates the Furnace Module at a to be determined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples of CdTe occur next. Upon completion of processing a single sample the carousel will deliver a subsequent sample to the furnace module. Purging of the Furnace Module with fresh processing gas occurs after the bake out and two samples of CdTe. Depending on degradation of ampoules the amount of purges can be increased but only if the resources are available. The remaining samples, include HgCdTe, HgZnTe, and an extended processing time of HgZnTe. Upon completion of the entire carousel of samples the furnace is returned to a standby mode. From the standby mode complete shutdown can occur.

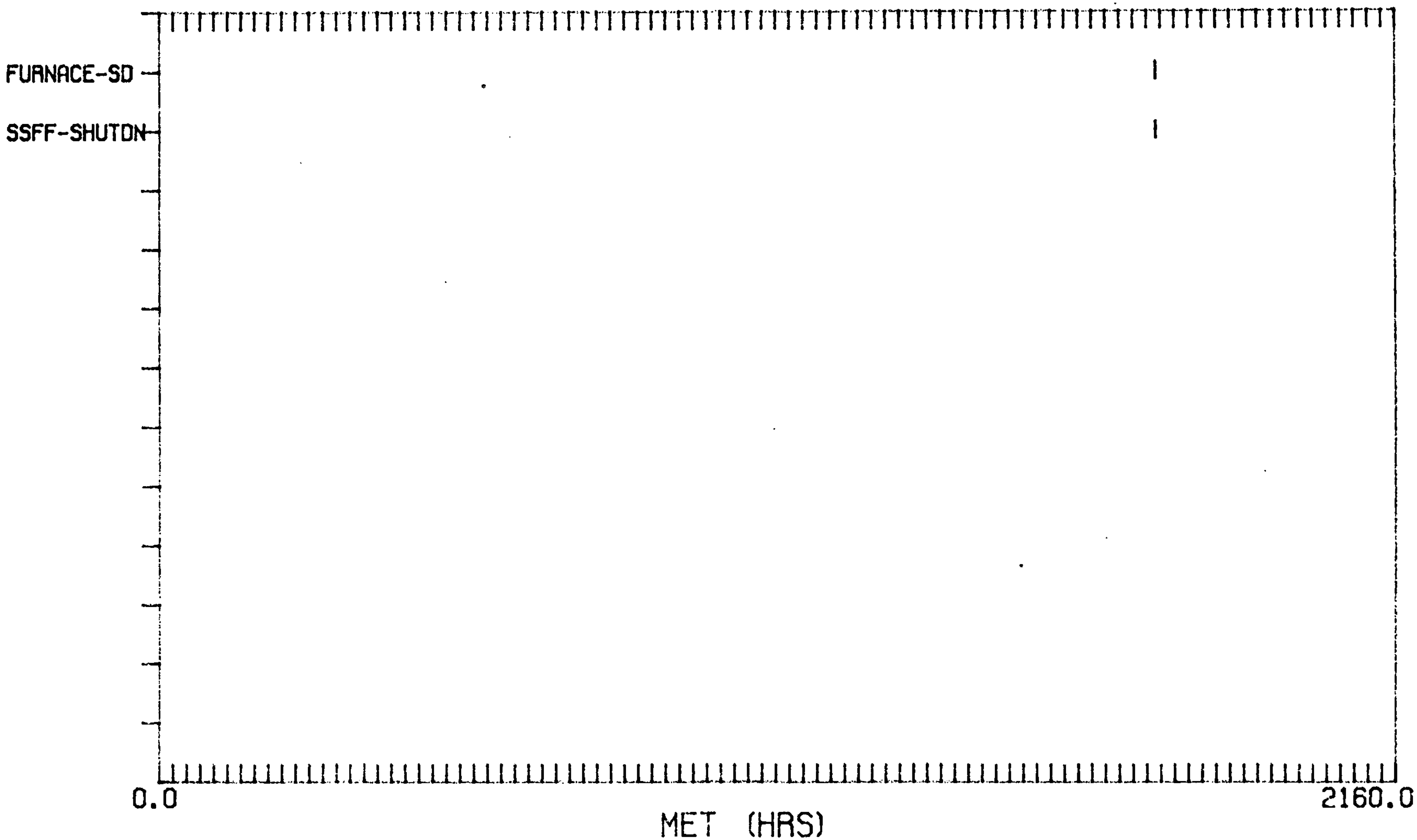
Shutdown occurs through a process of: reconfiguration of the SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration is required to vent the furnace of processing gas, configure the TCS into the core rack, and check that the furnace is in the home

position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

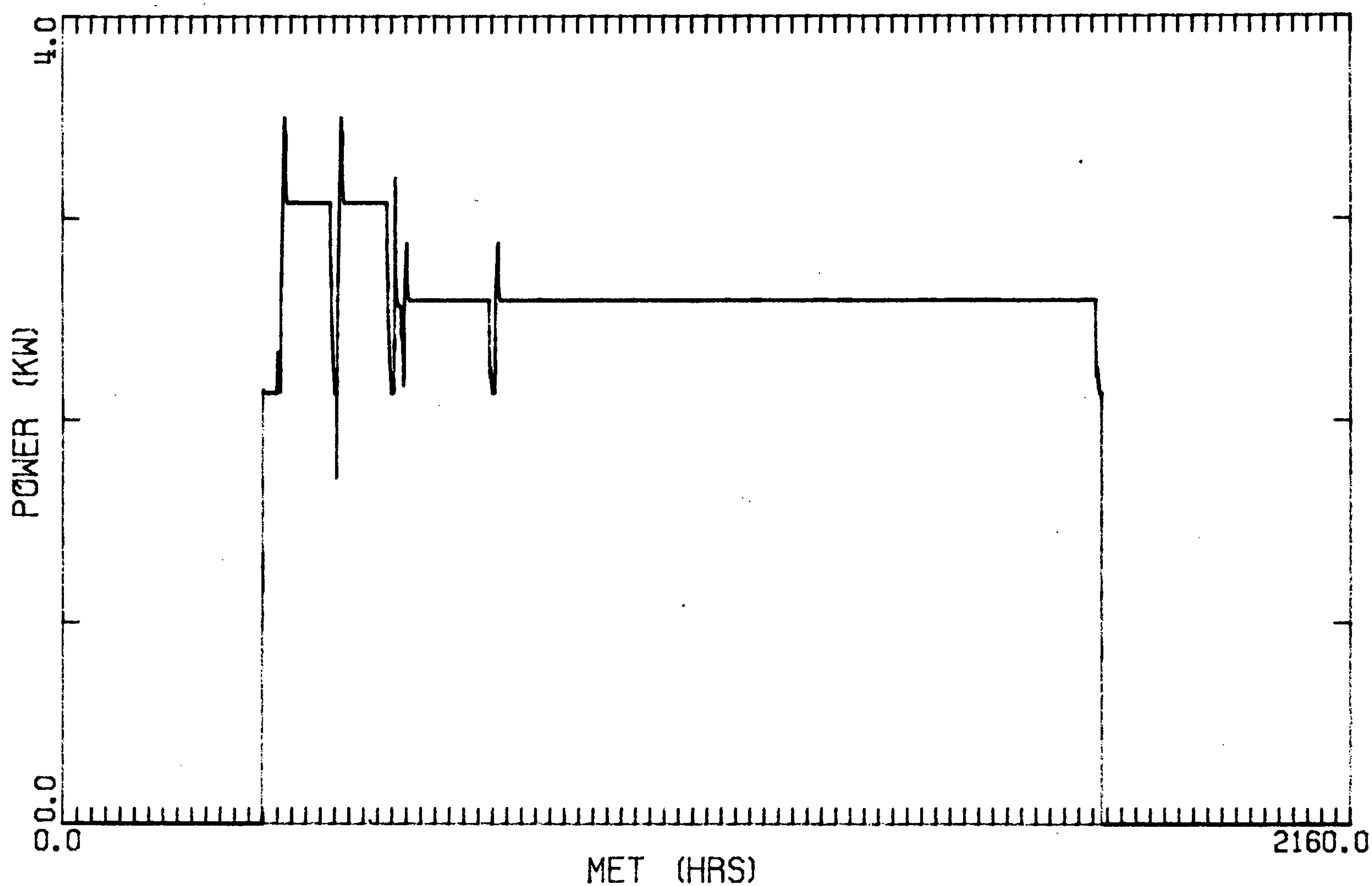
EXTENDED BASELINE



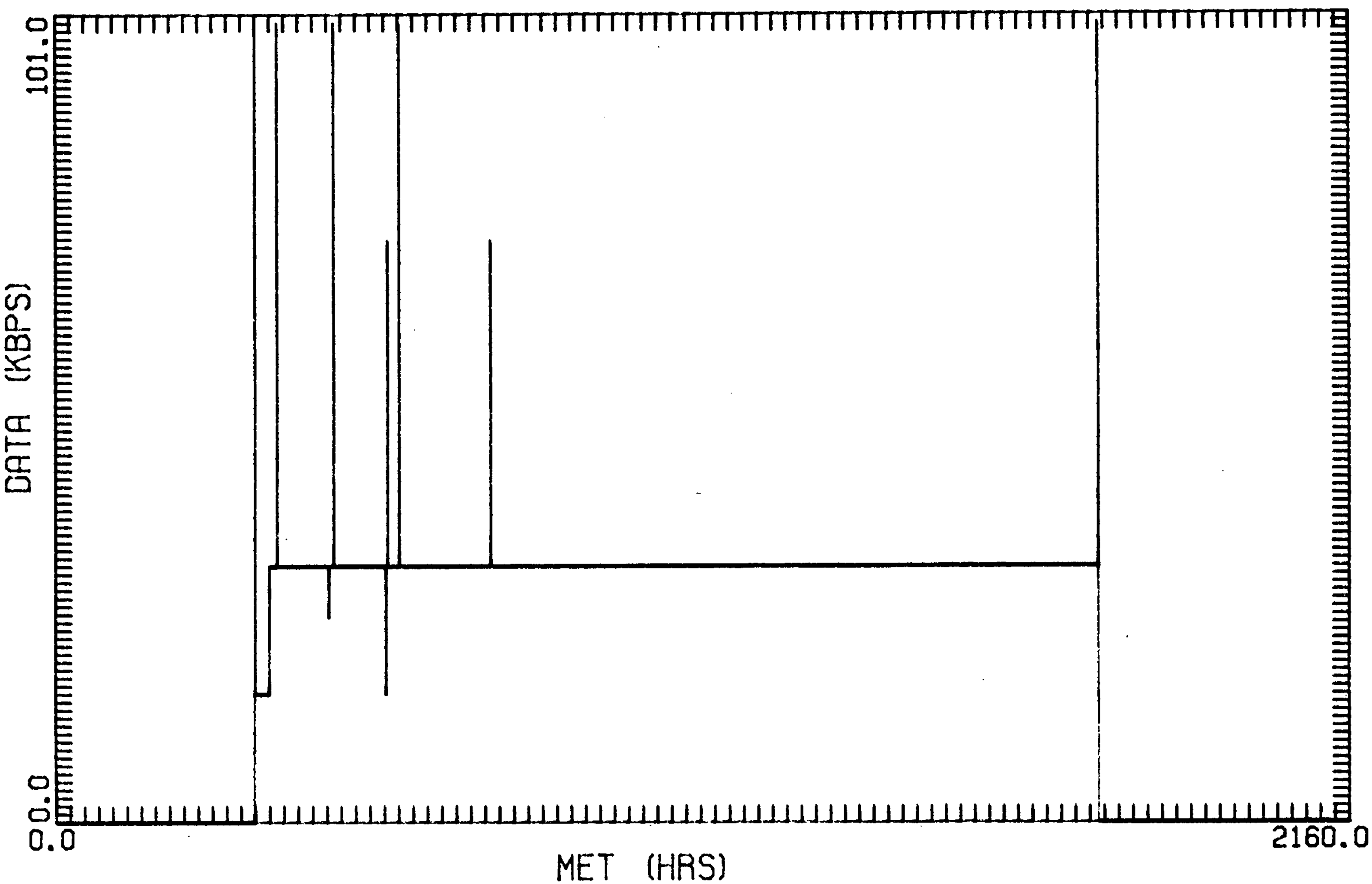
EXTENDED BASELINE



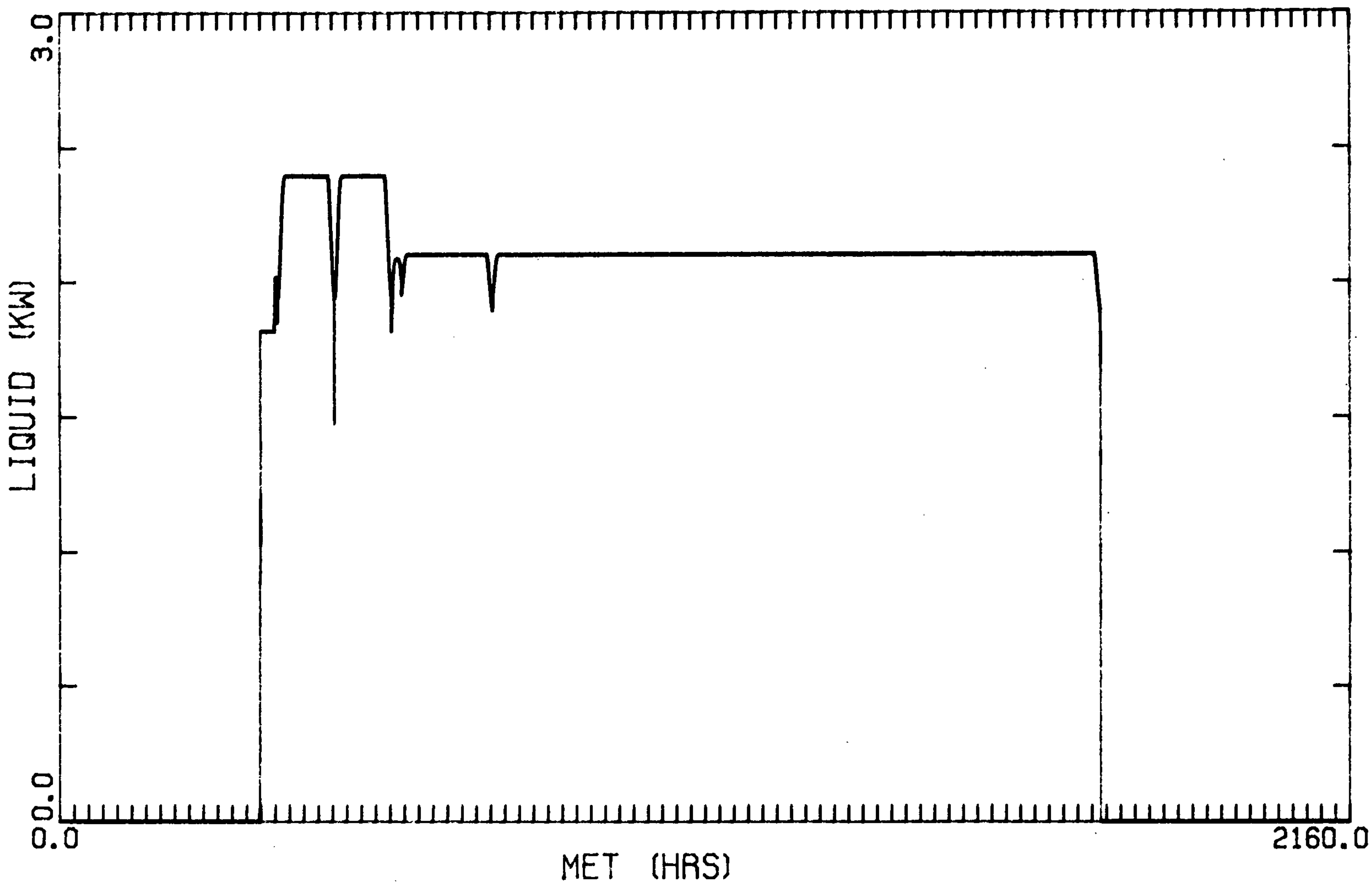
EXTENDED BASELINE



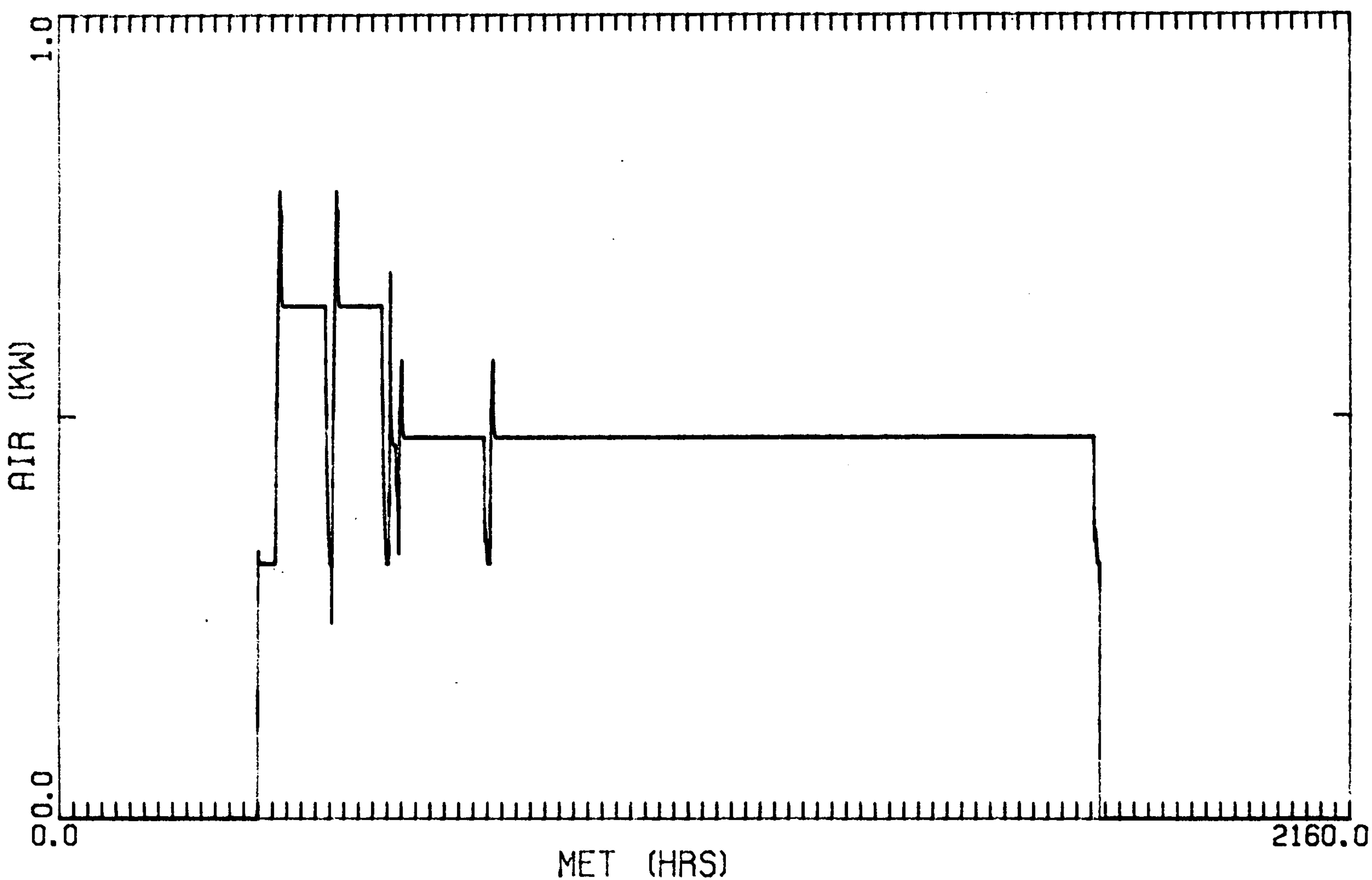
EXTENDED BASELINE



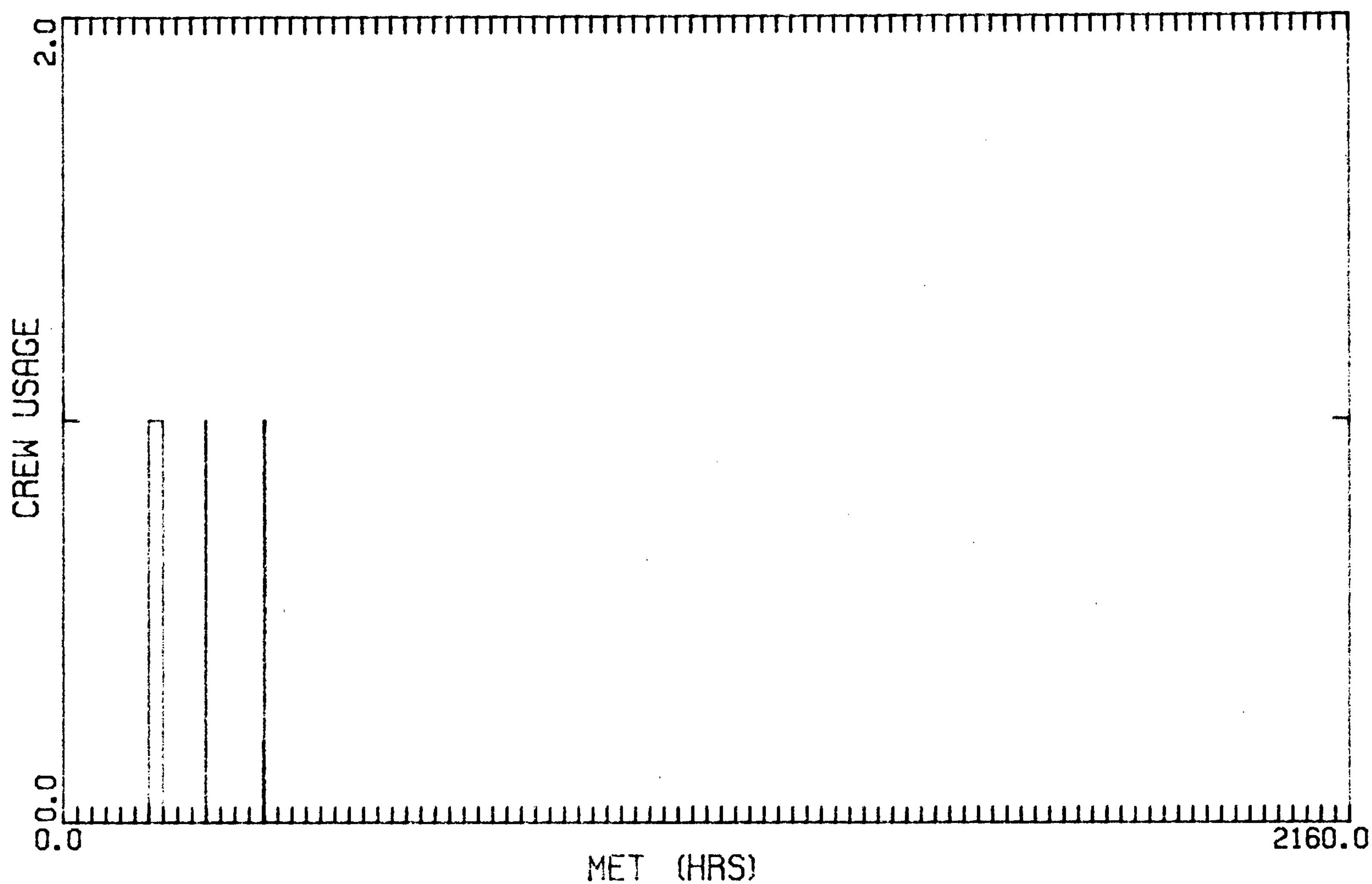
EXTENDED BASELINE



EXTENDED BASELINE



EXTENDED BASELINE



EXTENDED BASELINE

MODEL	SSFF-INSTL	INSERTED FROM	144.00	HRS TO	168.00	HRS
MODEL	PAYLOAD-ACT	INSERTED FROM	240.00	HRS TO	240.18	HRS
MODEL	CORE-ACT	INSERTED FROM	336.00	HRS TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED FROM	336.50	HRS TO	336.95	HRS
MODEL	MSE	INSERTED FROM	336.95	HRS TO	339.55	HRS
MODEL	STANDBY	INSERTED FROM	339.55	HRS TO	360.10	HRS
MODEL	BAKEOUT	INSERTED FROM	360.10	HRS TO	365.10	HRS
MODEL	CGF-CdTe	INSERTED FROM	365.10	HRS TO	460.00	HRS
MODEL	CGF-CdTe	INSERTED FROM	460.02	HRS TO	554.92	HRS
MODEL	PURGE	INSERTED FROM	554.92	HRS TO	555.68	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	555.68	HRS TO	572.18	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	572.18	HRS TO	724.88	HRS
MODEL	CGF-HgZnTe-A	INSERTED FROM	724.88	HRS TO	1743.47	HRS
MODEL	FURNACE-SD	INSERTED FROM	1743.47	HRS TO	1743.62	HRS
MODEL	SSFF-SHUTDN	INSERTED FROM	1743.62	HRS TO	1743.85	HRS

**** MAXIMUM RES1-POWER 3.498 KW
**** MAXIMUM RES2-DATA GENERATION 100.000 KBPS

**** TOTAL ENERGY RES1= 3704.42 KWH
**** TOTAL ENERGY RES2= 44698.60 KBPSH = 20114370 KBytes DATA VOLUME

GROUP 1	ENERGY RES1 =	3704.42	RES2 =	44698.60	CREW TIME (M-Hr) =	26.25
GROUP 2	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 3	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 2.6313

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
SSFF-INSTL	1	1	100.00000000%
PAYLOAD-ACT	1	1	100.00000000%
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%

MSE	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT	1	1	100.00000000%
CGF-CdTe	2	2	100.00000000%
PURGE	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
FURNACE-SD	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

EXTENDED BASELINE

**** MAXIMUM RES1-LIQUID 2.397 KW
**** MAXIMUM RES2-AIR 0.781 KW

**** TOTAL ENERGY RES1= 2988.88 KWH
**** TOTAL ENERGY RES2= 683.45 KWH

GROUP 1 ENERGY RES1 =	2988.88	RES2 =	683.45	CREW TIME (M-Hr) =	0.00
GROUP 2 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 3 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 4 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 5 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 6 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 7 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 8 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 9 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 10 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 11 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 12 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 13 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 14 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 15 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 16 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 17 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 18 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 19 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 20 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00

VARIABLE SCENARIO DESCRIPTION

Scenario #3 represents the functionality of SSFF in handling mixtures of long and short processing times. It also provide data for potential combinations of samples. A characterization sample, HgCdTe, HgZnTe, GaAs, and CdTe are the samples processed. The first three samples processed are a characterization sample, CdTe and GaAs and require a short, a long, and a short processing time respectively. The three remaining samples (HgZnTe, HgCdTe and an extended processing time of HgZnTe) are subsequentially processed in a random order. Random order refers to processing a long or short sample followed by two sample of opposite processing duration (e.g. short, long, long). The third scenario was modeled to provide variations in sample processing times as could be seen in a typical 90 day mission. The Installation of the core rack and one furnace rack is not include in the data for this scenario. The procedure and data of Installation is identical to scenarios 1 and 2.

VARIABLE SCENARIO OVERVIEW

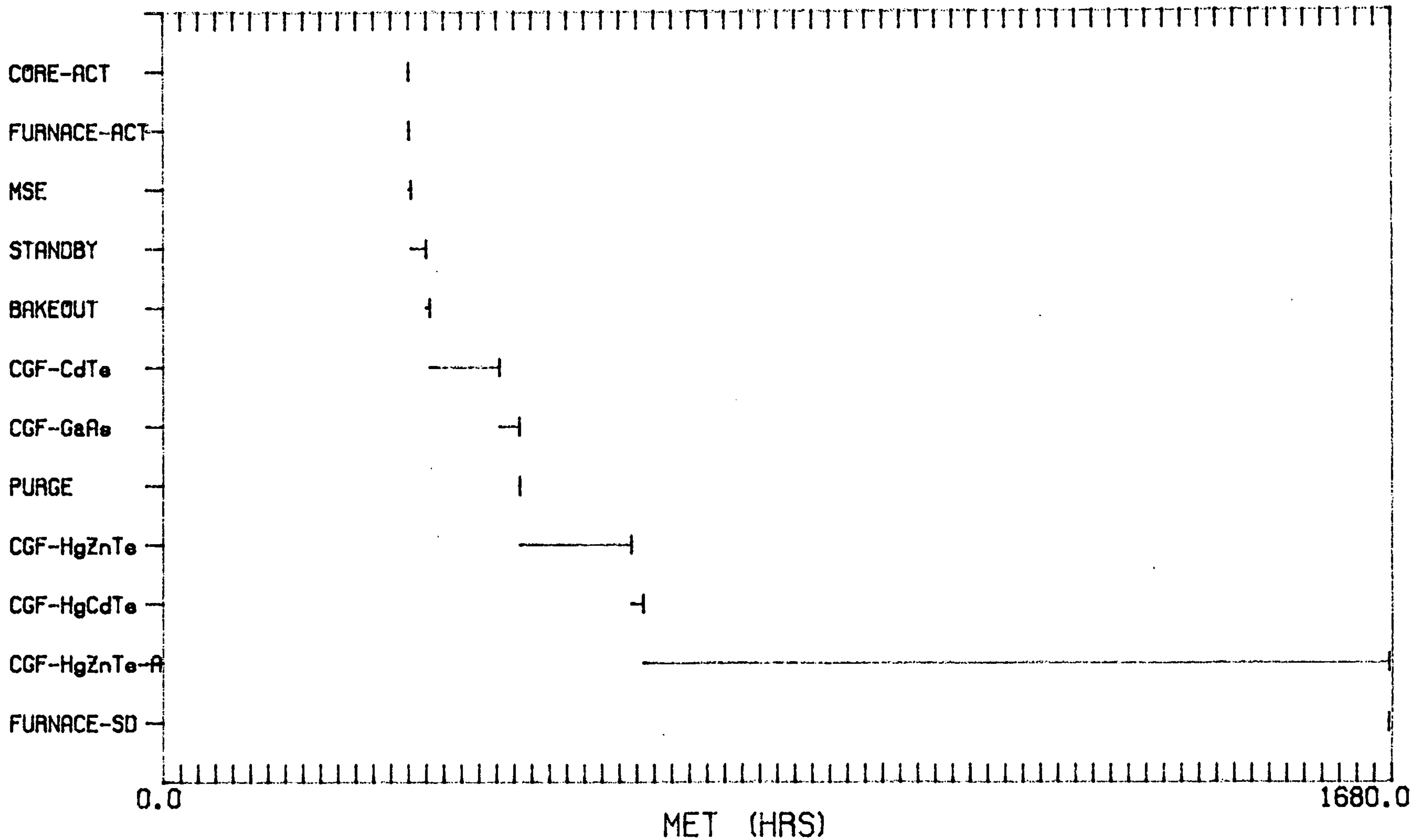
The operation of this SSFF scenario is as follows: Installation of the core rack and Furnace Module #1 occur first. Upon completion and checkout of equipment, activation will follow. Activation of the core equipment and distributed equipment occur respectively. The SSFF then reaches a standby condition where power consumption for subsystems are at normal operating amounts and the furnace module power consumption is at zero. The SSFF will fall back to these levels at several times during the 90 day mission. Samples are then loaded by the crew. Samples are loaded while in a Manual Sample Exchange mode. This mode allows the SSFF subsystems to remain in standby while the furnace module is in safe condition for crew interaction. The furnace is purged and filled with argon for processing of samples. At this point during Man-Tended Configuration the furnaces will remain at Standby until the crew leaves the SSF. Processing will occur upon crew departure from SSF to minimize unnecessary vibrational disturbances. The time for completion of the activities listed above occur within the first 15 days of the 90 day mission. This allows for crew checkout of all systems and correction of any problems if necessary .

Upon crew departure a signal from the CCU will occur for the Furnace Module to power up and start the processing cycle. The first sample to be processed is a calibration and bakeout sample This calibrates the Furnace Module at a to be determined time limit and proceeds with a bakeout of approximately 5 hours. Upon completion of processing a single sample the carousel will deliver a subsequent sample to the furnace module. The first three samples in the carousel are the characterization sample, CdTe and GaAs. The remaining samples include HgCdTe, HgZnTe, and an extended processing time of HgZnTe. Purging of the furnace with fresh argon occurs after the

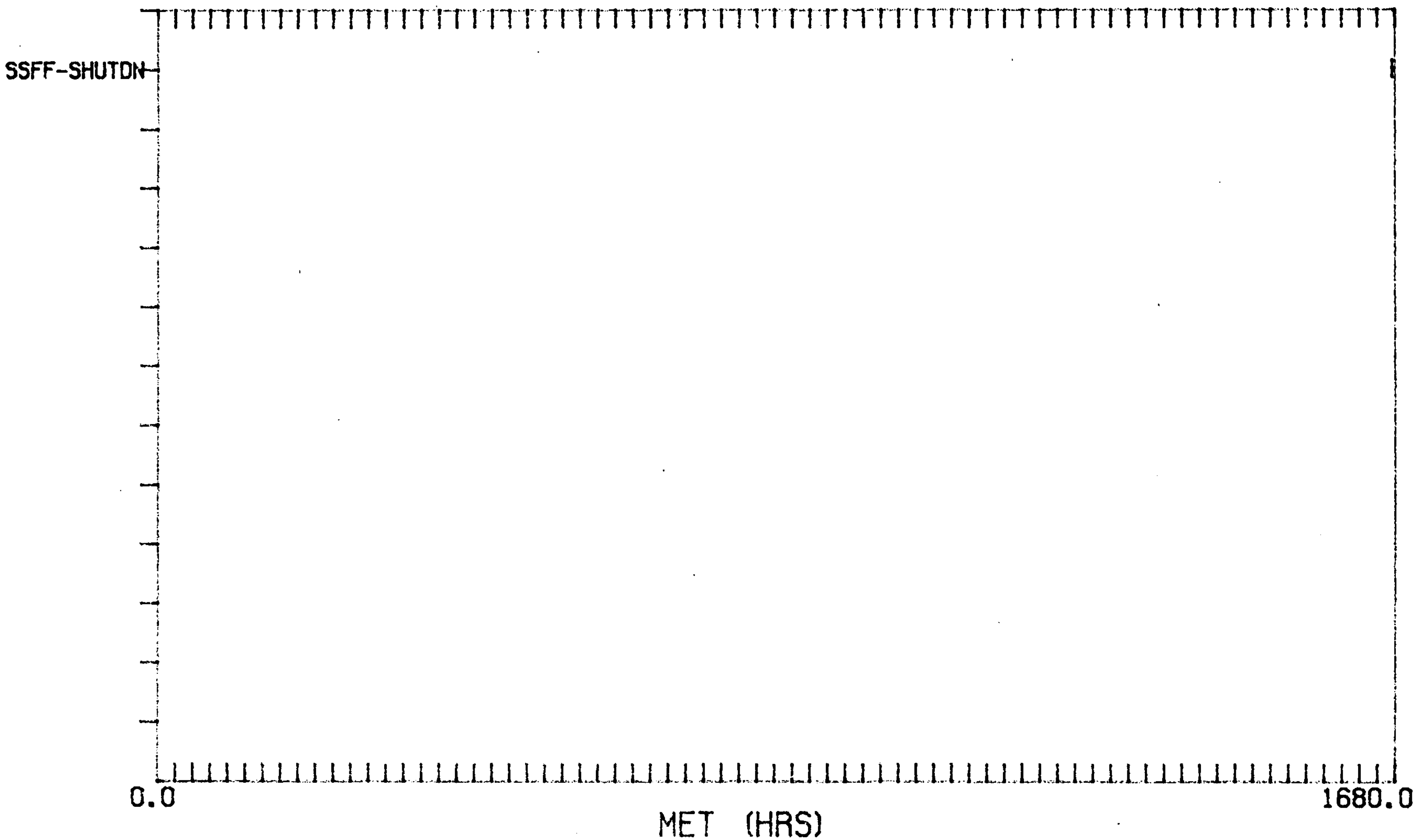
first three samples in the scenario described. Upon completion of the entire carousel of samples the furnace is returned to a standby mode.From the standby mode complete shutdown can occur.

Shutdown occurs through a process of: reconfiguration of the SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration is required to vent the furnace of processing gas, configure the TCS into the core rack, and check that the furnace is in the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

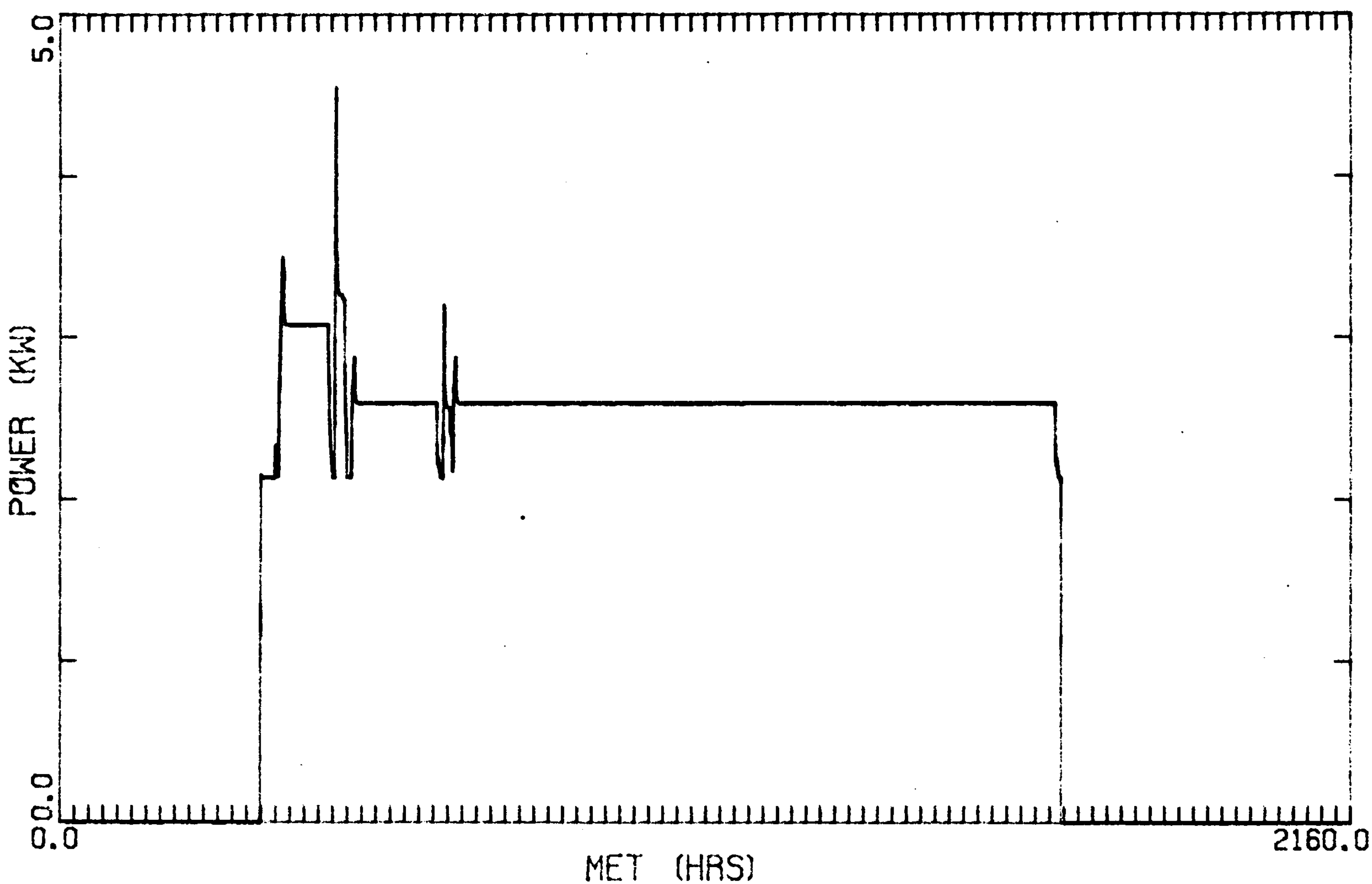
VARIABLE SCENARIO



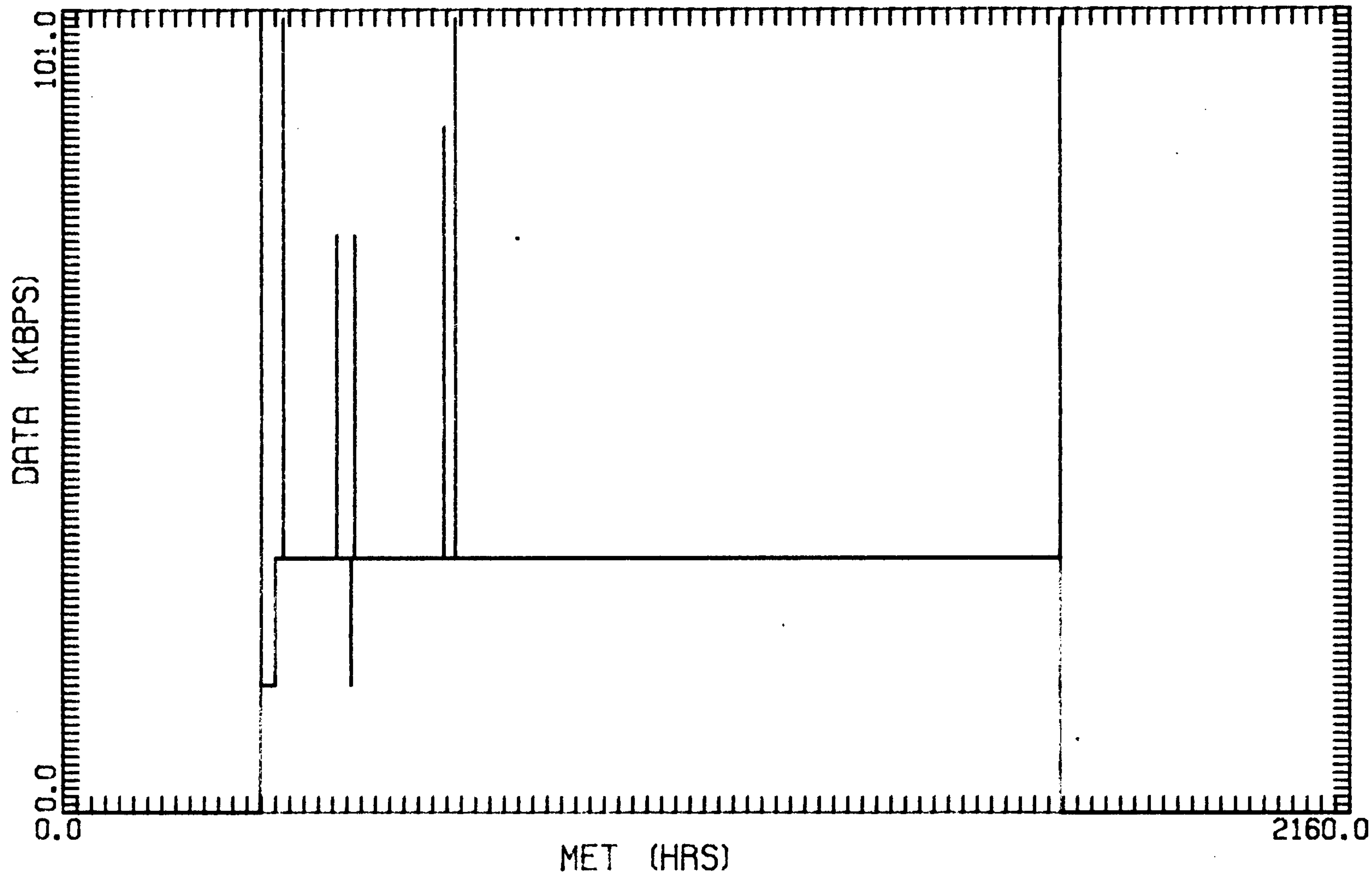
VARIABLE SCENARIO



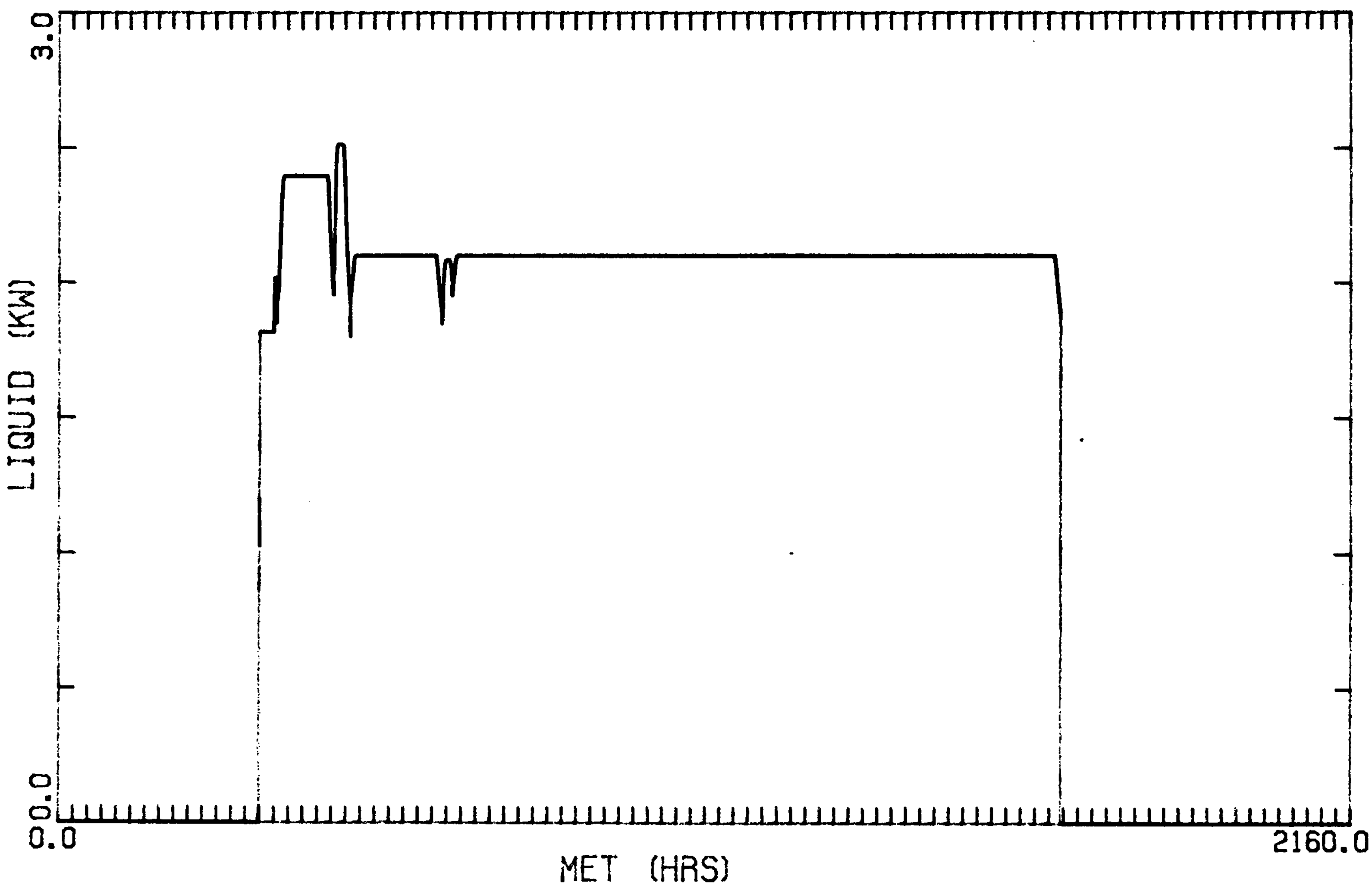
VARIABLE SCENARIO



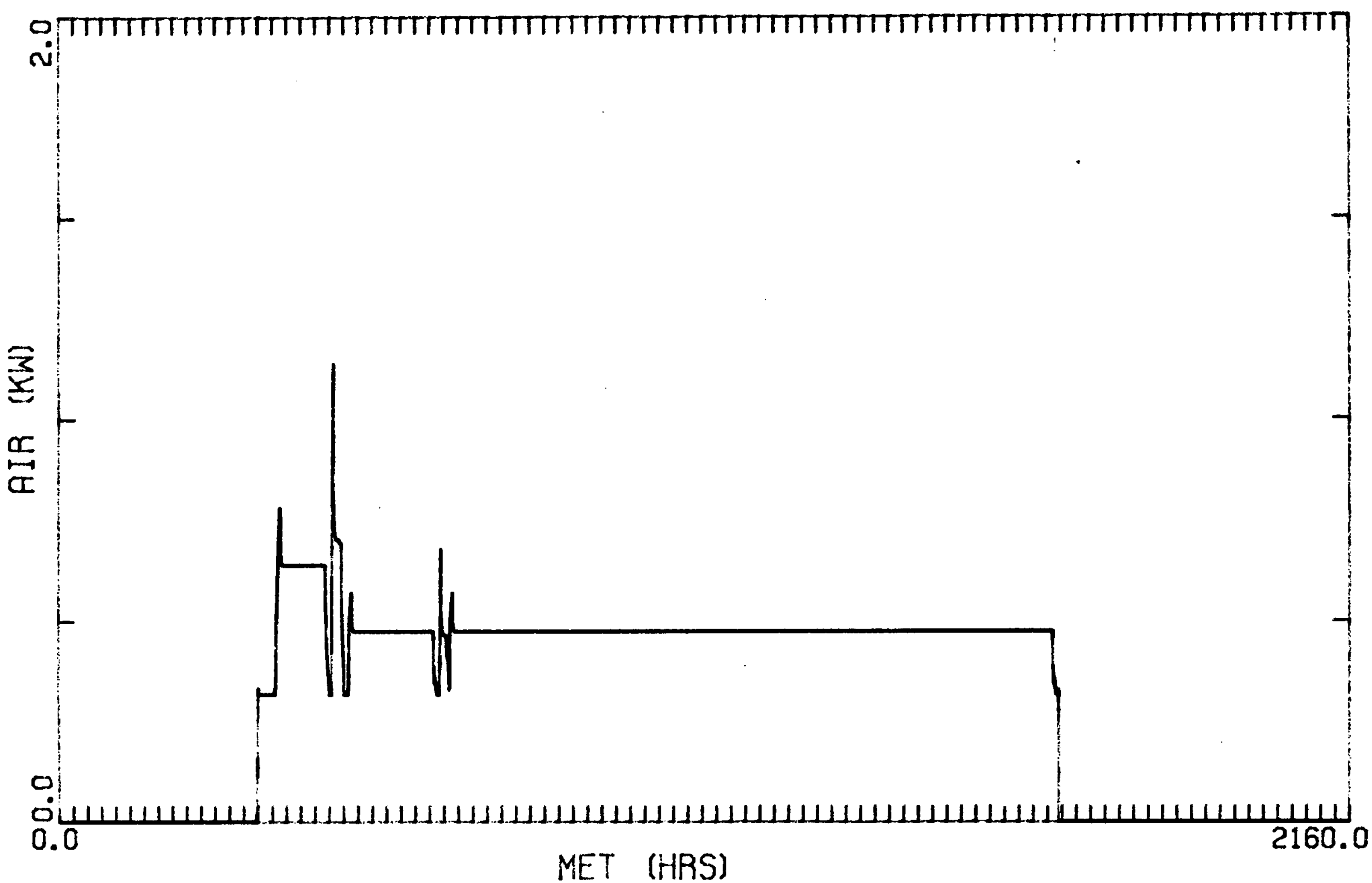
VARIABLE SCENARIO



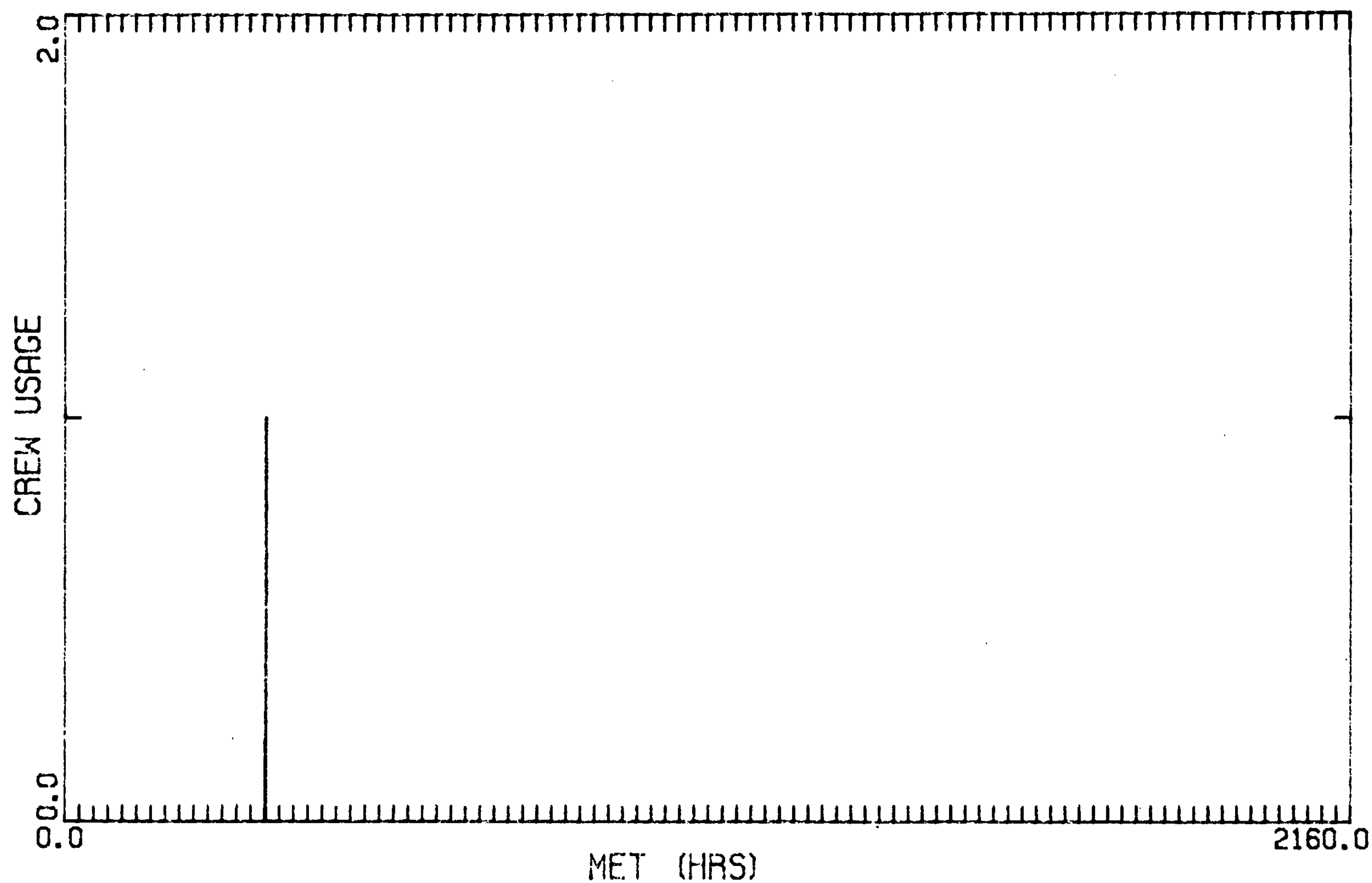
VARIABLE SCENARIO



VARIABLE SCENARIO



VARIABLE SCENARIØ



VARIABLE SCENARIO

MODEL	CORE-ACT	INSERTED	FROM	336.00	HRS	TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED	FROM	336.50	HRS	TO	336.95	HRS
MODEL	MSE	INSERTED	FROM	336.95	HRS	TO	339.55	HRS
MODEL	STANDBY	INSERTED	FROM	339.55	HRS	TO	360.10	HRS
MODEL	BAKEOUT	INSERTED	FROM	360.10	HRS	TO	365.10	HRS
MODEL	CGF-CdTe	INSERTED	FROM	365.10	HRS	TO	460.00	HRS
MODEL	CGF-GaAs	INSERTED	FROM	460.00	HRS	TO	487.20	HRS
MODEL	PURGE	INSERTED	FROM	487.20	HRS	TO	487.97	HRS
MODEL	CGF-HgZnTe	INSERTED	FROM	487.97	HRS	TO	640.67	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	640.67	HRS	TO	657.17	HRS
MODEL	CGF-HgZnTe-A	INSERTED	FROM	657.17	HRS	TO	1675.75	HRS
MODEL	FURNACE-SD	INSERTED	FROM	1675.75	HRS	TO	1675.90	HRS
MODEL	SSFF-SHUTDN	INSERTED	FROM	1675.90	HRS	TO	1676.13	HRS

**** MAXIMUM RES1-POWER 4.559 KW
**** MAXIMUM RES2-DATA GENERATION 100.000 KBPS

**** TOTAL ENERGY RES1= 3501.62 KWH
**** TOTAL ENERGY RES2= 42532.20 KBPSH = 19139490 KBytes DATA VOLUME

GROUP	1	ENERGY RES1 =	3501.62	RES2 =	42532.20	CREW TIME	(M-Hr) =	2.07
GROUP	2	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	3	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00
GROUP	20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 2.613 KW

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT	1	1	100.00000000%
CGF-CdTe	1	1	100.00000000%
CGF-GaAs	1	1	100.00000000%
PURGE	1	1	100.00000000%

CGF-HgZnTe	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
FURNACE-SD	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

VARIABLE SCENARIO

```
**** MAXIMUM RES1-LIQUID     2.514 KW
**** MAXIMUM RES2-AIR        1.141 KW


**** TOTAL ENERGY RES1=    2830.86 KWH
**** TOTAL ENERGY RES2=     642.22 KWH
GROUP  1 ENERGY RES1 =     2830.86 RES2 =     642.22 CREW TIME (M-Hr) =        0.00
GROUP  2 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  3 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  4 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  5 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  6 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  7 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  8 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  9 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 10 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 11 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 12 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 13 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 14 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 15 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 16 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 17 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 18 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 19 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 20 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
```

<u>ALL SHORT SAMPLE DESCRIPTION</u>

Scenario # 4 reflects a possible scenario of processing a set of six samples during the first 15 days of MTC. The samples used are a characterization sample, GaAs and HgCdTe. GaAs and HgCdTe are repeated for the remaining five samples because of their short processing times. This scenario generates data that may be useful when processing during a utilization flight. The Installation of the core rack and one furnace rack is not include in the data for this scenario. The procedure and data of Installation is identical to scenarios 1 and 2.

<u>ALL SHORT SAMPLES SCENARIO OVERVIEW</u>

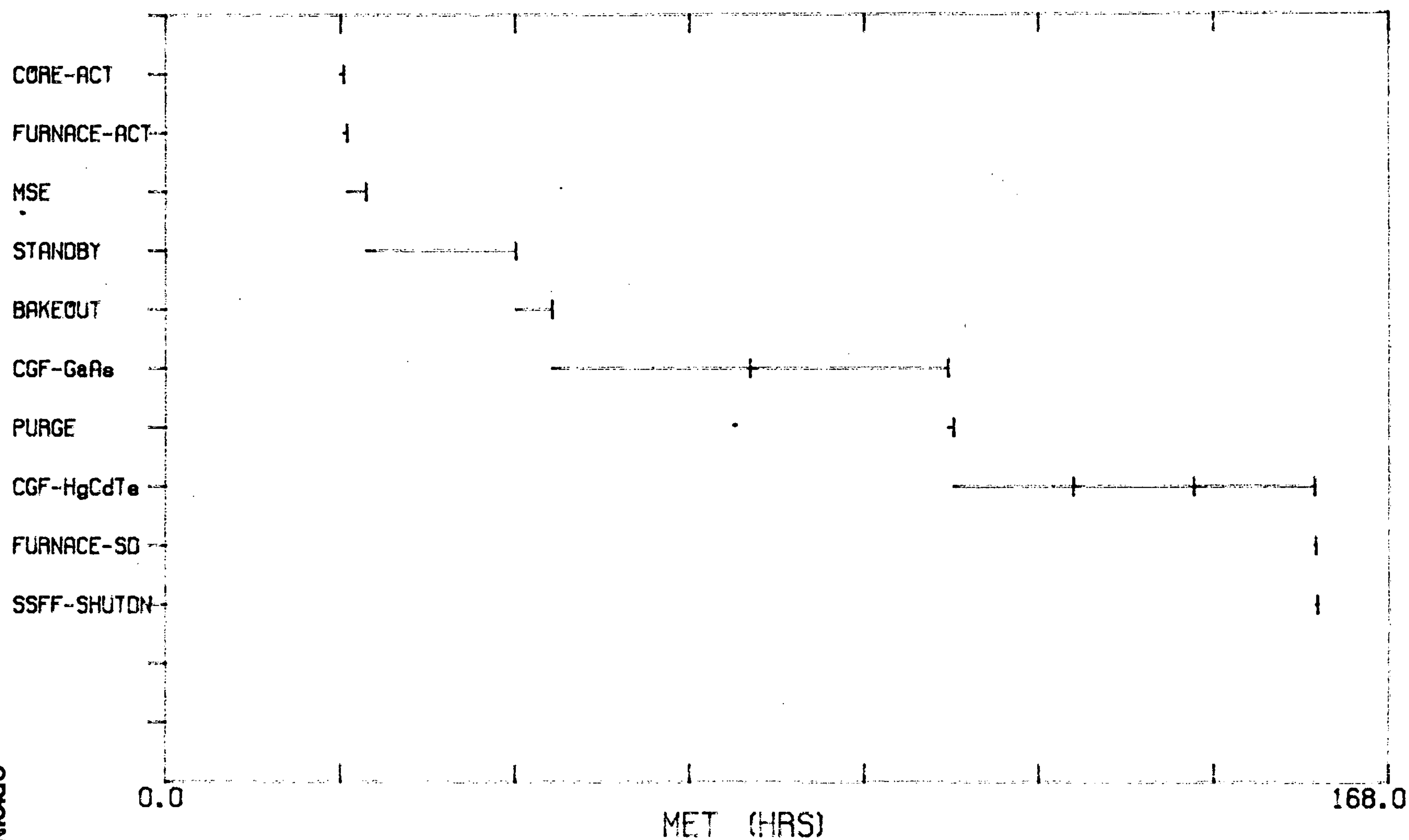
The operation of this SSFF scenario is as follows: Installation of the core rack and Furnace Module #1 occur first. Upon completion and checkout of equipment, activation will follow. Activation of the core equipment and distributed equipment occur respectively. The SSFF then reaches a standby condition where power consumption for subsystems are at normal operating amounts and the furnace module power consumption is at zero. The SSFF will fall back to these levels at several times during the 90 day mission. Samples are then loaded by the crew. Samples are loaded while in a Manual Sample Exchange mode. This mode allows the SSFF subsystems to remain in standby while the furnace module is in safe condition for crew interaction. The furnace is purged and filled with argon for processing of samples. At this point during Man-Tended Configuration the furnaces will remain at Standby until the crew leaves the SSF. Processing will occur upon crew departure from SSF to minimize unnecessary vibrational disturbances. The time for completion of the activities listed above occur within the first 15 days of the 90 day mission. This allows for crew checkout of all systems and correction of any problems if necessary .

A signal from the CCU will occur for the Furnace Module to power up and start the processing cycle. The first sample to be processed is a calibration and bakeout sample This calibrates the Furnace Module at a to be determined time limit and proceeds with a bakeout of approximately 5 hours. Upon completion of processing a single sample the carousel will deliver a subsequent sample to the furnace module. The first three samples in the carousel are the characterization sample, and two samples of GaAs. The remaining three samples include repeated samples of HgCdTe. Purging of the furnace with fresh processing gas occurs after the first three samples. Upon completion of the entire carousel of samples the furnace is returned to a standby mode.

From the standby mode complete shutdown or continued operation can occur. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and

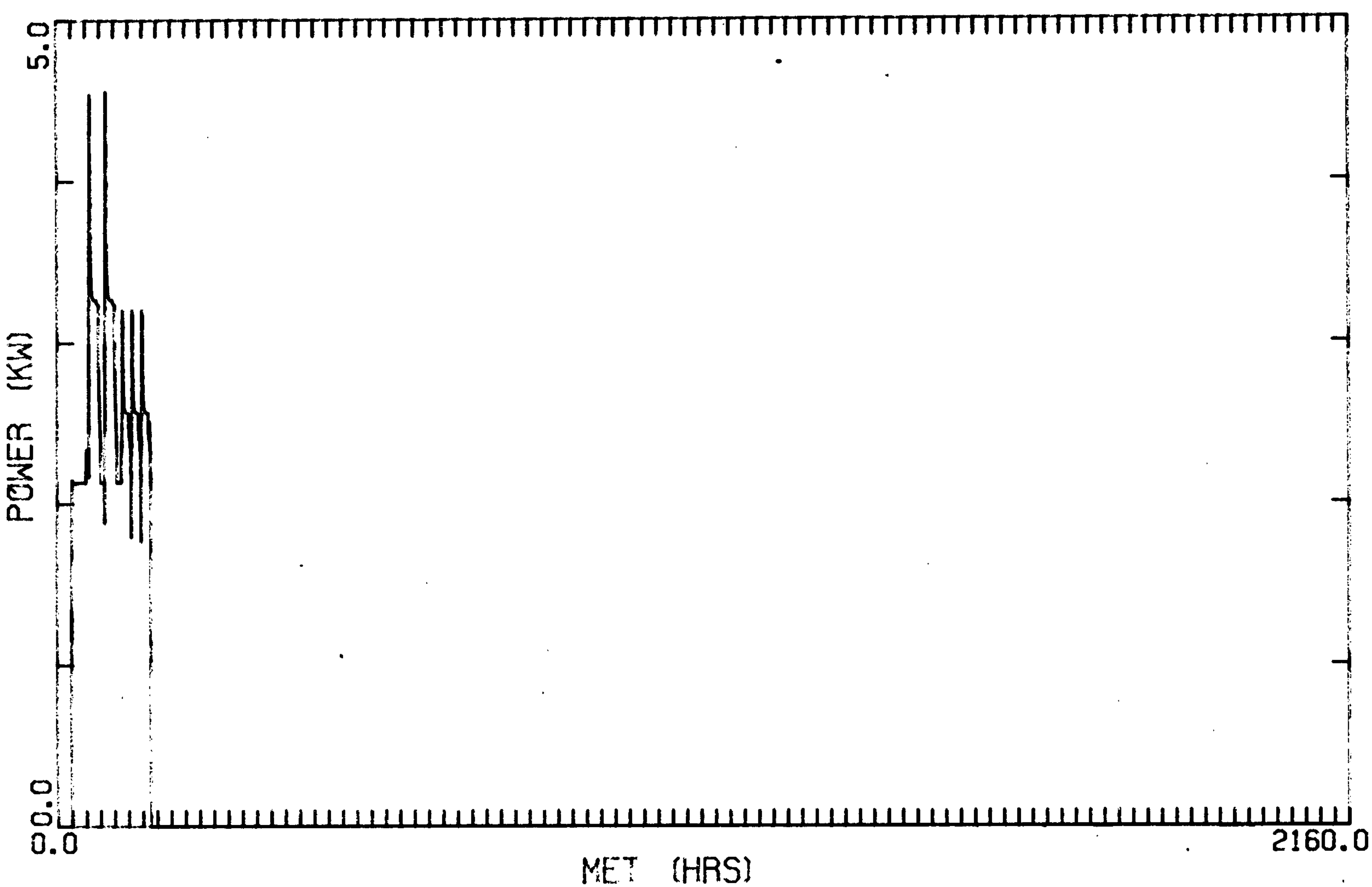
deactivation of core equipment. Reconfiguration requires the furnace to vent processing gas from the furnace, configure the TCS into the core rack, and place the furnace into the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown. Another option exists for continued operation. This can occur on missions were crew will be available to exchange samples into the carousel. From the standby mode, the manual sample exchange can be utilized and another set of samples loaded. The process continues as before processing samples in that carousel until it returns to standby mode. The cycle continues with an option to shutdown the SSFF after every completed carousel.

ALL SHØRT SCENARIØ

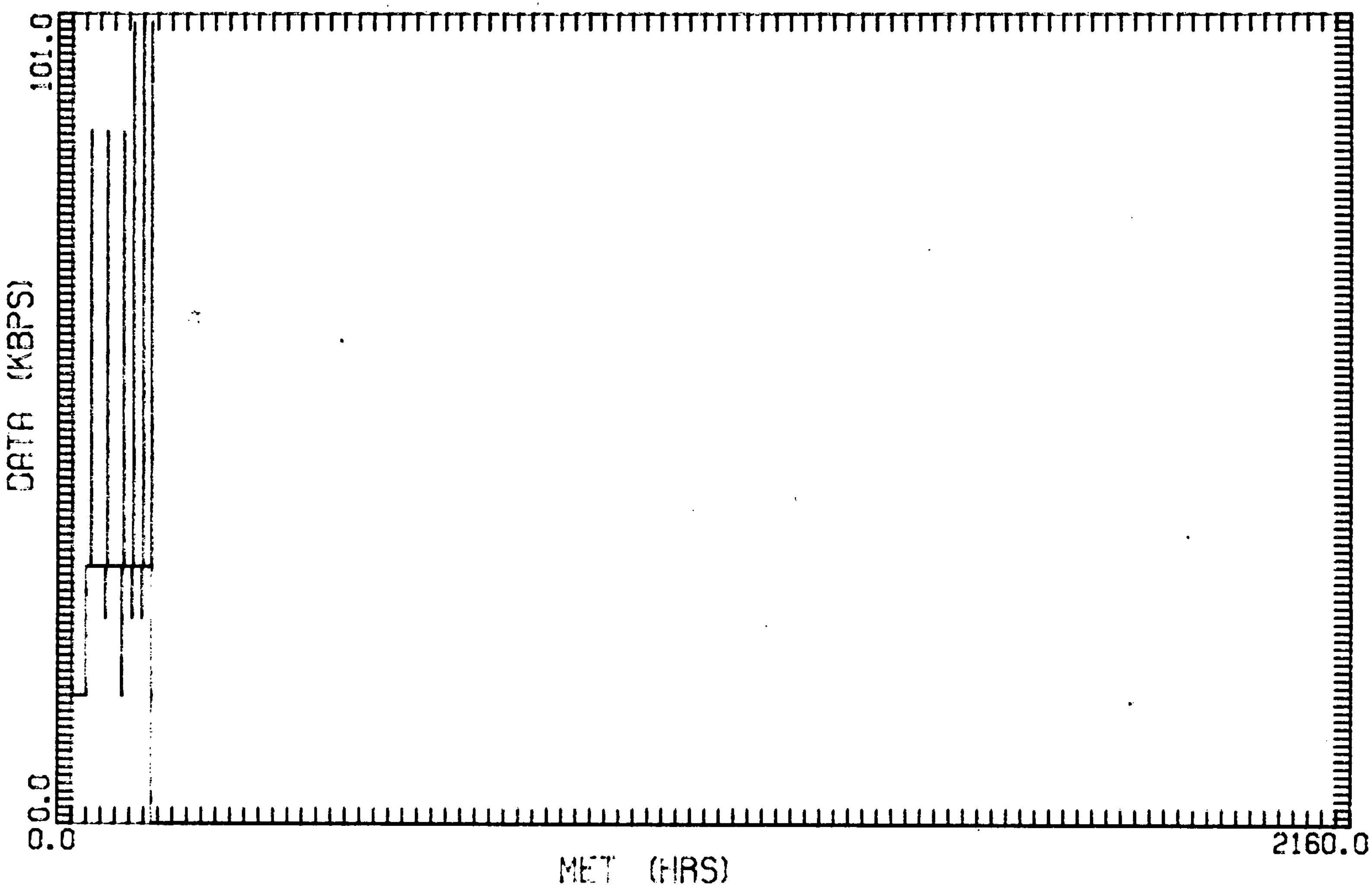


ORIGINAL PAGE IS
OF POOR QUALITY

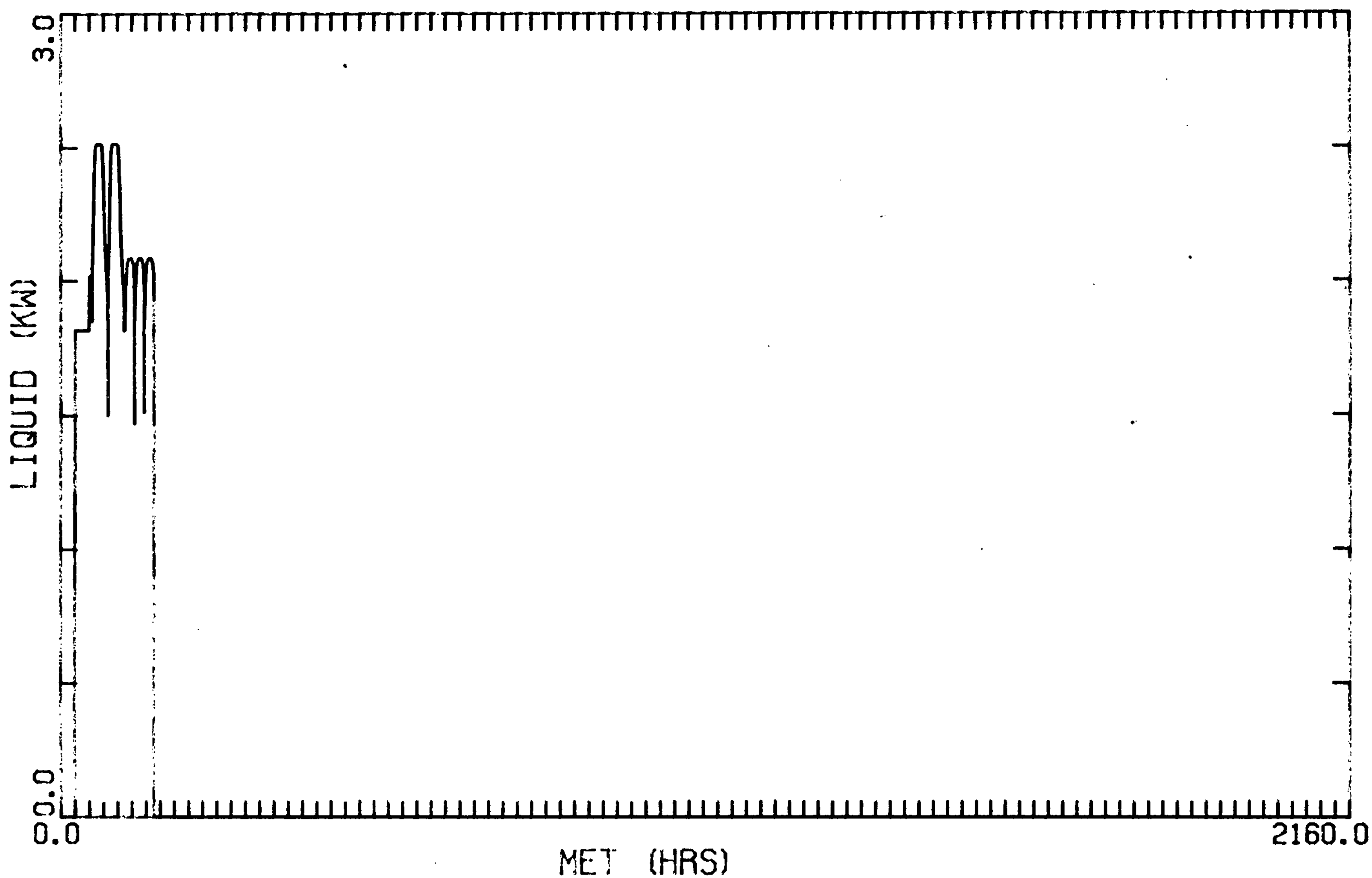
ALL SHØRT SCENARIØ



ALL SHØRT SCENARIØ



ALL SHØRT SCENARIO



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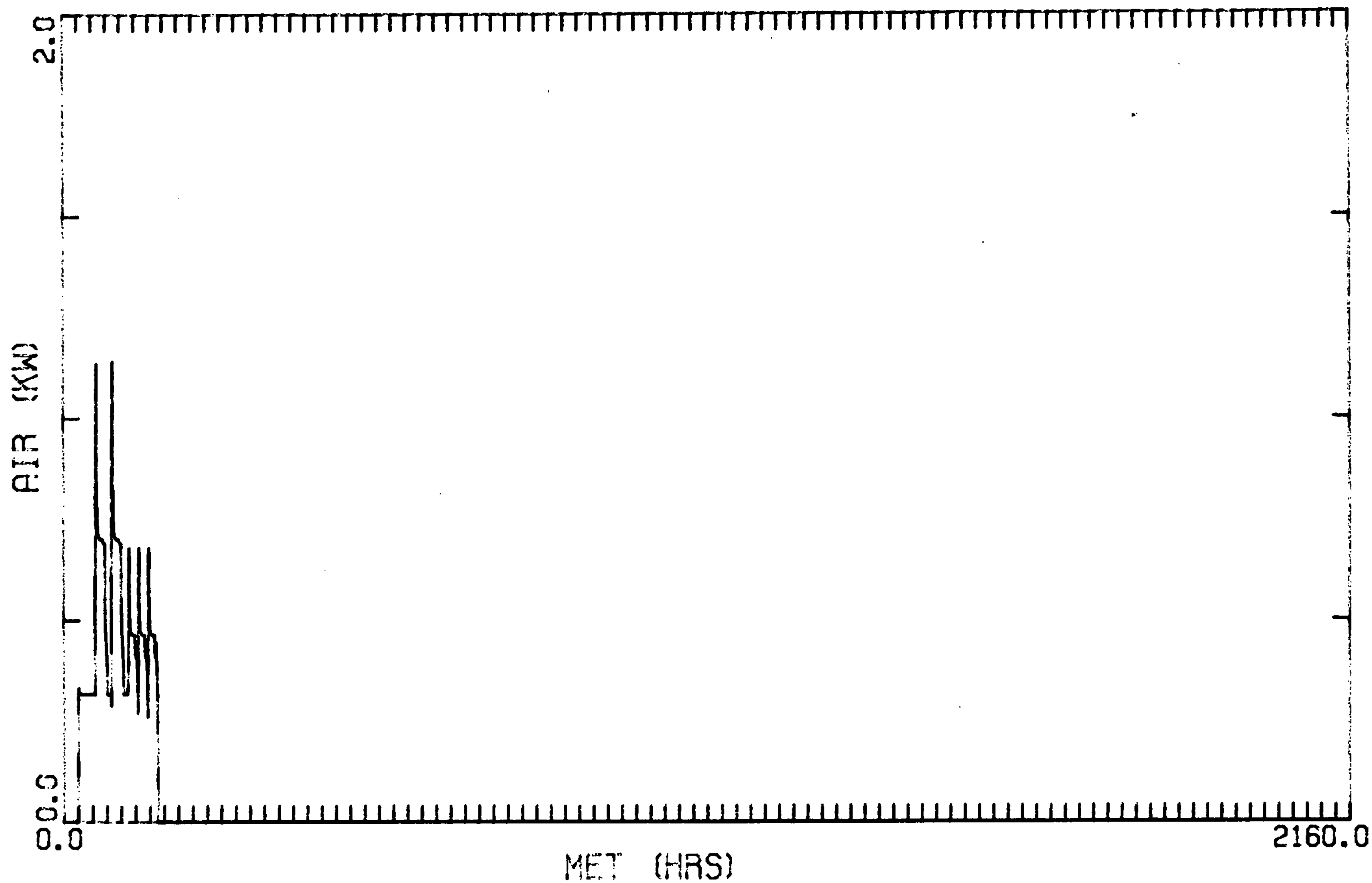
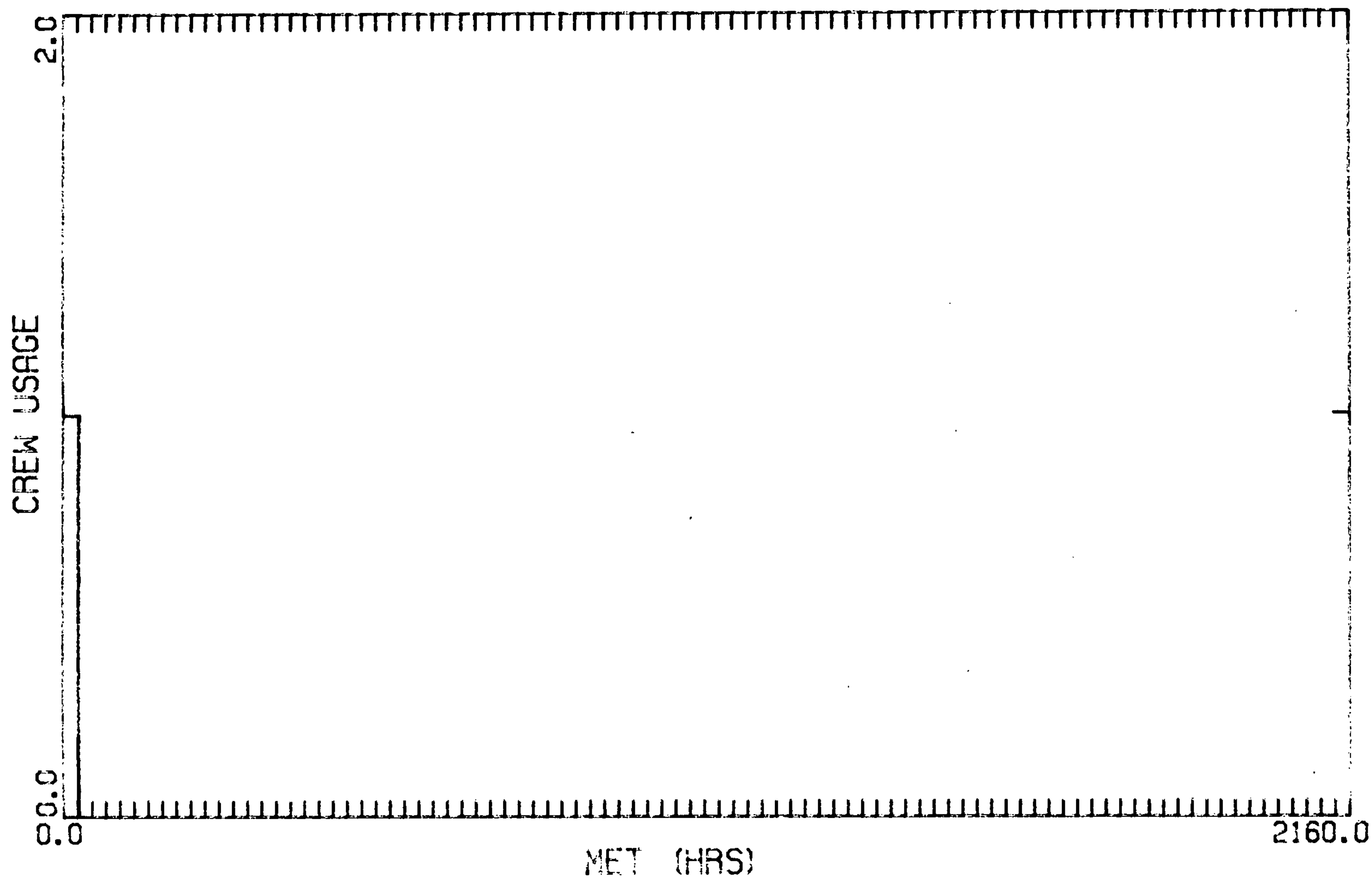


ALL SHORT SCENARIO



ALL SHORT SCENARIO

```
MODEL CORE-ACT      INSERTED FROM    24.00 HRS TO    24.50 HRS
MODEL FURNACE-ACT   INSERTED FROM    24.50 HRS TO    24.95 HRS
MODEL MSE           INSERTED FROM    24.95 HRS TO    27.55 HRS
MODEL STANDBY       INSERTED FROM    27.55 HRS TO    48.10 HRS
MODEL BAKEOUT       INSERTED FROM    48.10 HRS TO    53.10 HRS
MODEL CGF-GaAs      INSERTED FROM    53.10 HRS TO    80.30 HRS
MODEL CGF-GaAs      INSERTED FROM    80.32 HRS TO   107.52 HRS
MODEL PURGE         INSERTED FROM   107.52 HRS TO   108.28 HRS
MODEL CGF-HgCdTe    INSERTED FROM   108.28 HRS TO   124.78 HRS
MODEL CGF-HgCdTe    INSERTED FROM   124.80 HRS TO   141.30 HRS
MODEL CGF-HgCdTe    INSERTED FROM   141.32 HRS TO   157.82 HRS
MODEL FURNACE-SD    INSERTED FROM   157.82 HRS TO   157.97 HRS
MODEL SSFF-SHUTDN   INSERTED FROM   157.97 HRS TO   158.20 HRS


**** MAXIMUM RES1-     4.559 KW
**** MAXIMUM RES2-   100.000 KBPS


**** TOTAL ENERGY RES1=     352.13 KWH
**** TOTAL ENERGY RES2=    3940.73 KBPSH = 1773328.5 KBytes DATA VOLUME
GROUP  1 ENERGY RES1 =     352.13 RES2 =    3940.73 CREW TIME (M-Hr) =      2.07
GROUP  2 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  3 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00


MAXIMUM NUMBER OF CREW =     1.000

AVG POWER SSFF = 2.6239

EXPERIMENTS         NO.RUNS  DESIRED RUNS  PERCENTAGE
CORE-ACT               1           1      100.00000000%
FURNACE-ACT            1           1      100.00000000%
MSE                    1           1      100.00000000%
STANDBY                1           1      100.00000000%
BAKEOUT                1           1      100.00000000%
CGF-GaAs               2           2      100.00000000%
PURGE                  1           1      100.00000000%
CGF-HgCdTe             3           3      100.00000000%
```

FURNACE-SD	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

ALL SHORT SCENARIO

```
**** MAXIMUM RES1-LIQUID     2.514 KW
**** MAXIMUM RES2-AIR        1.141 KW


**** TOTAL ENERGY RES1=    283.88 KWH
**** TOTAL ENERGY RES2=     64.79 KWH
GROUP  1 ENERGY RES1 =     283.88 RES2 =      64.79 CREW TIME (M-Hr) =        0.00
GROUP  2 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  3 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
```

REQUESTED SHUTDOWN SCENARIO DESCRIPTION

Scenario # 5 exhibits the possibility of an interruption in the processing of a carousel of samples. The samples processed are HgCdTe, HgZnTe (extended processing time), HgZnTe, GaAs, and CdTe. They are processed in random order. The scenario includes a SSFF shutdown procedure upon request from SSF. This shutdown request will occur before all of the samples can be processed.

REQUESTED SHUTDOWN SCENARIO OVERVIEW

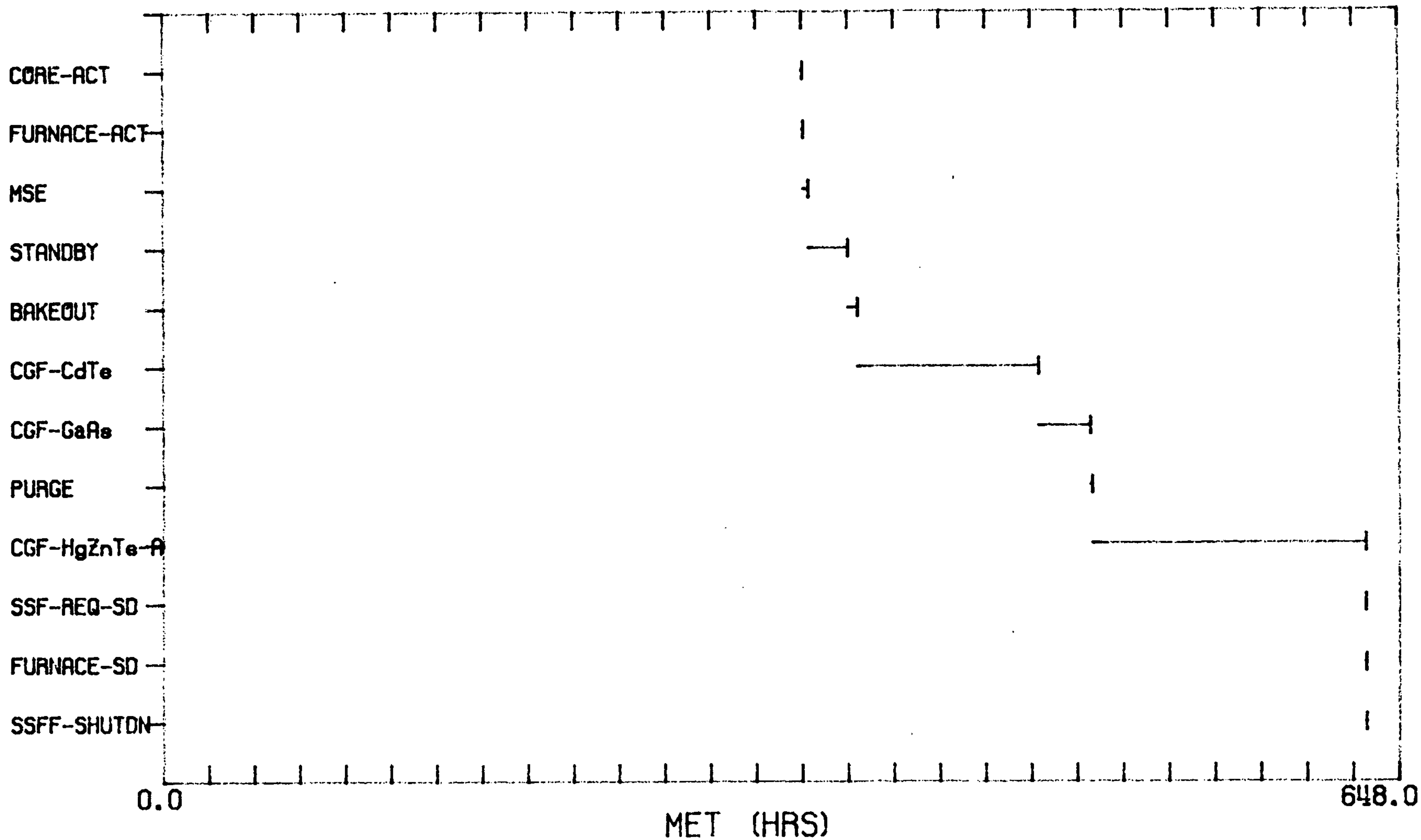
The operation of the SSFF in this scenario is as follows: Installation of the core rack and Furnace Module #1 occur on Utilization Flight TBD. The checkout of all hoses, lines, and equipment will be performed by the crew during Installation. Upon completion of the Installation stage, activation will occur. Activation occurs with the core equipment and distributed equipment respectively. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within the furnace rack. The Furnace Module is included in this activation step. After all the equipment is powered and allowed to warm-up, the SSFF reaches a standby mode. This Standby mode is when power consumption for subsystems are at normal operating amounts and the Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the Furnace Module is in a safe condition for crew interaction. After the samples are loaded in the Furnace Module, it is purged with Nitrogen. The furnace is then configured for a processing of samples. The configurement of the furnace depends on what sample is being processed. The furnace is vented of the nitrogen and filled with a processing gas. Argon is the processing gas in this scenario. At this point during Man-Tended Configuration the furnaces will remain at Standby mode until the crew leaves the SSF. Processing will occur upon crew departure from SSF to minimize vibrational disturbances. The time for completion of the activities listed above occur within the first 15 days of the 90 day mission. This will be the only time crew will be available for checkout of proper operation of systems and correction of any problems.

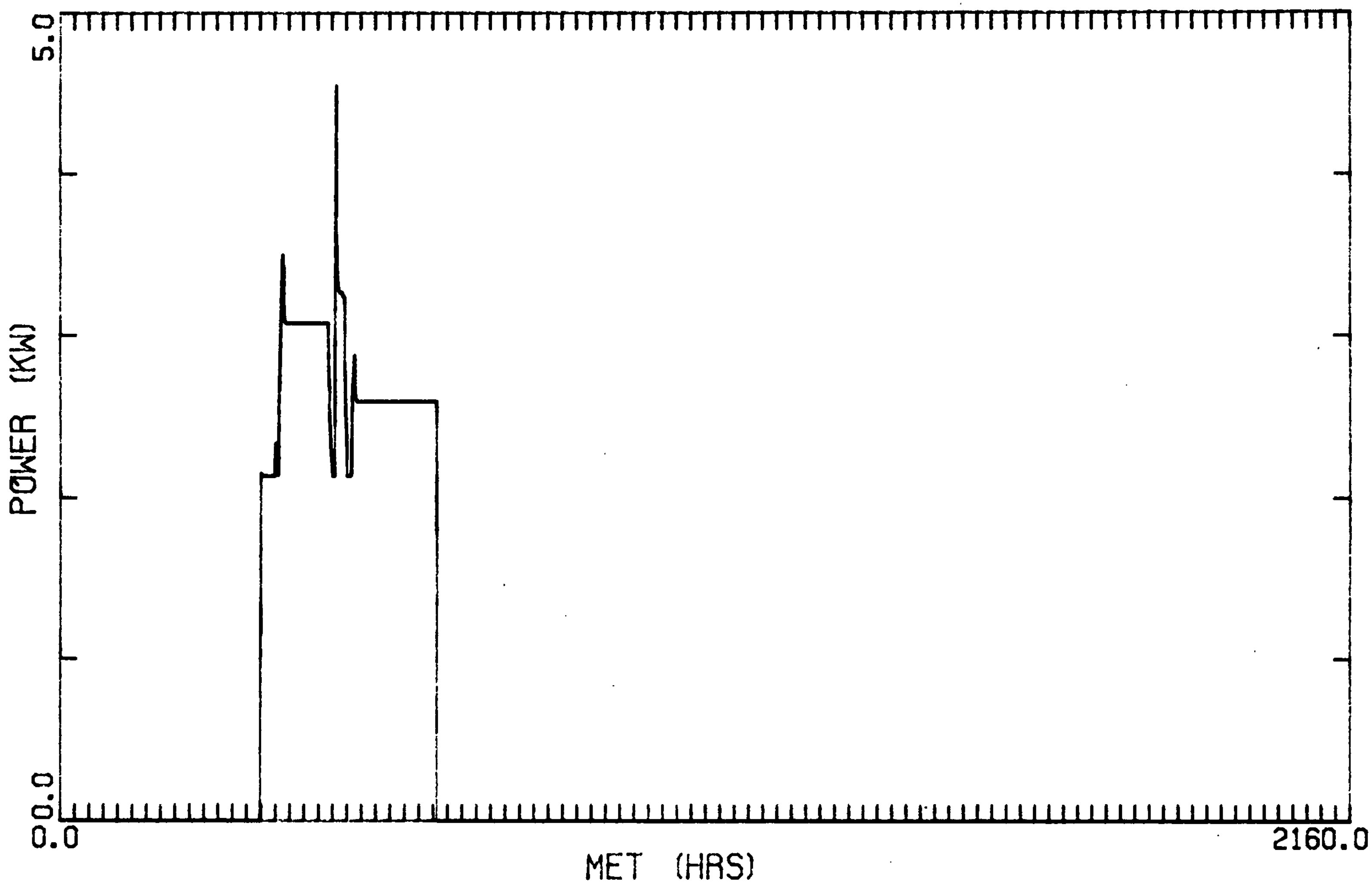
Upon crew departure a signal from the Core Control Unit (CCU) will allow for the Furnace Module to power up and start the processing cycle. The first sample to be processed is a calibration and bakeout sample. This sample calibrates the furnace at a predetermined time limit and proceeds with a bakeout of moisture for approximately 5 hours. Processing of two samples occurs next. They include CdTe and GaAs. Upon completion of processing a single sample the

carousel within the furnace module will deliver a subsequent sample to be processed. A purge of the furnace with fresh processing gas occurs after these three samples. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). An extended sample of HgZnTe is processed after a new supply of argon gas is contained within the furnace module. At approximately 142 hours into the processing of HgZnTe, a request from SSF to shutdown the SSFF is received by the CCU. The CCU immediately terminates power to the furnace module and the shutdown procedure will begin. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration of SSFF requires the furnace to vent processing gas from the furnace module and to place the furnace into the home position. The TCS can be configured, for a short time, to aid in cooling the furnace module. If necessary, deactivation of the distributed equipment occurs followed by deactivation of the core equipment. In the shutdown of the core equipment, the TCS pump package and CCU will be the last components shutdown. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

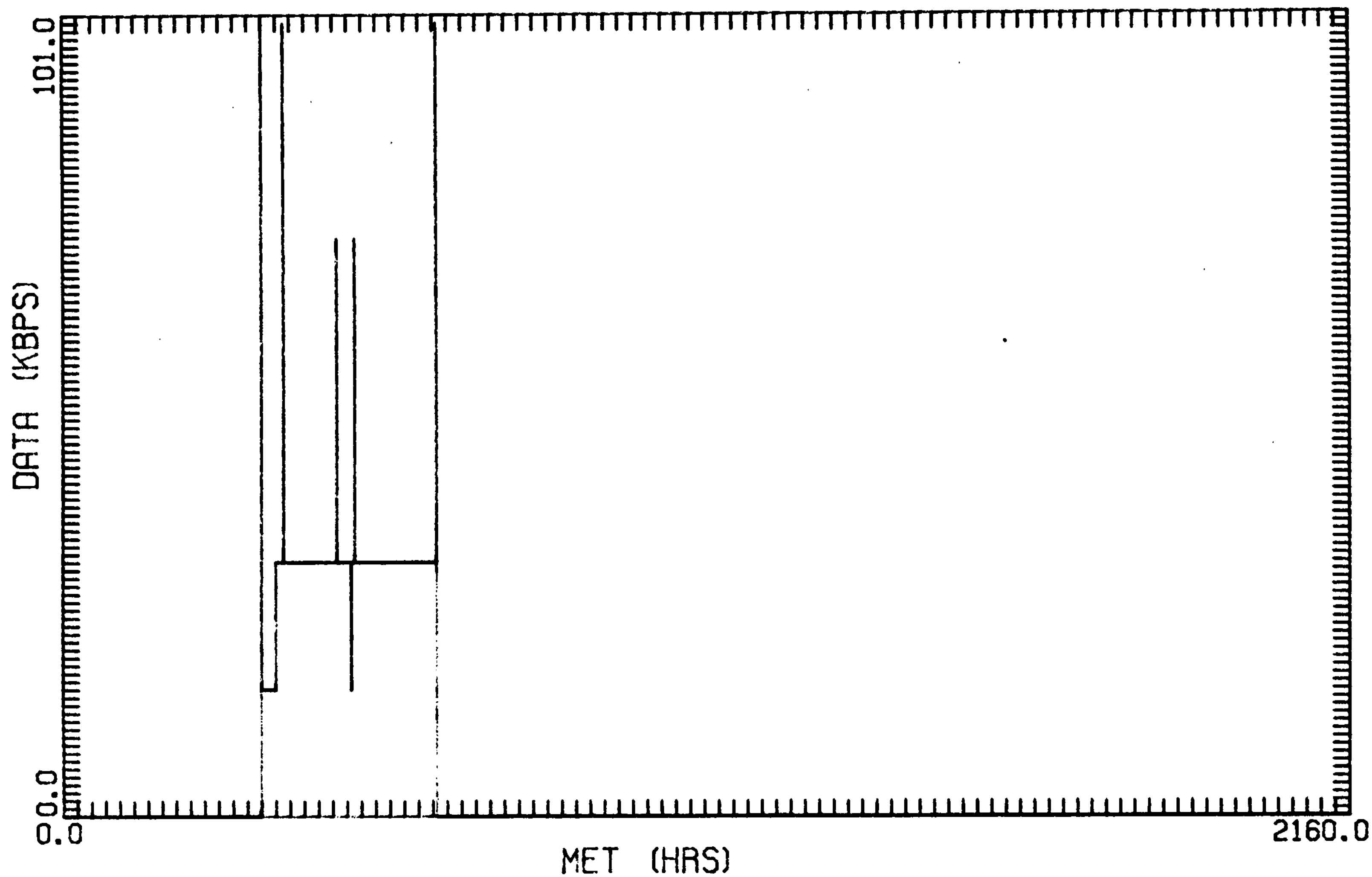
REQUESTED SHUTDØWN



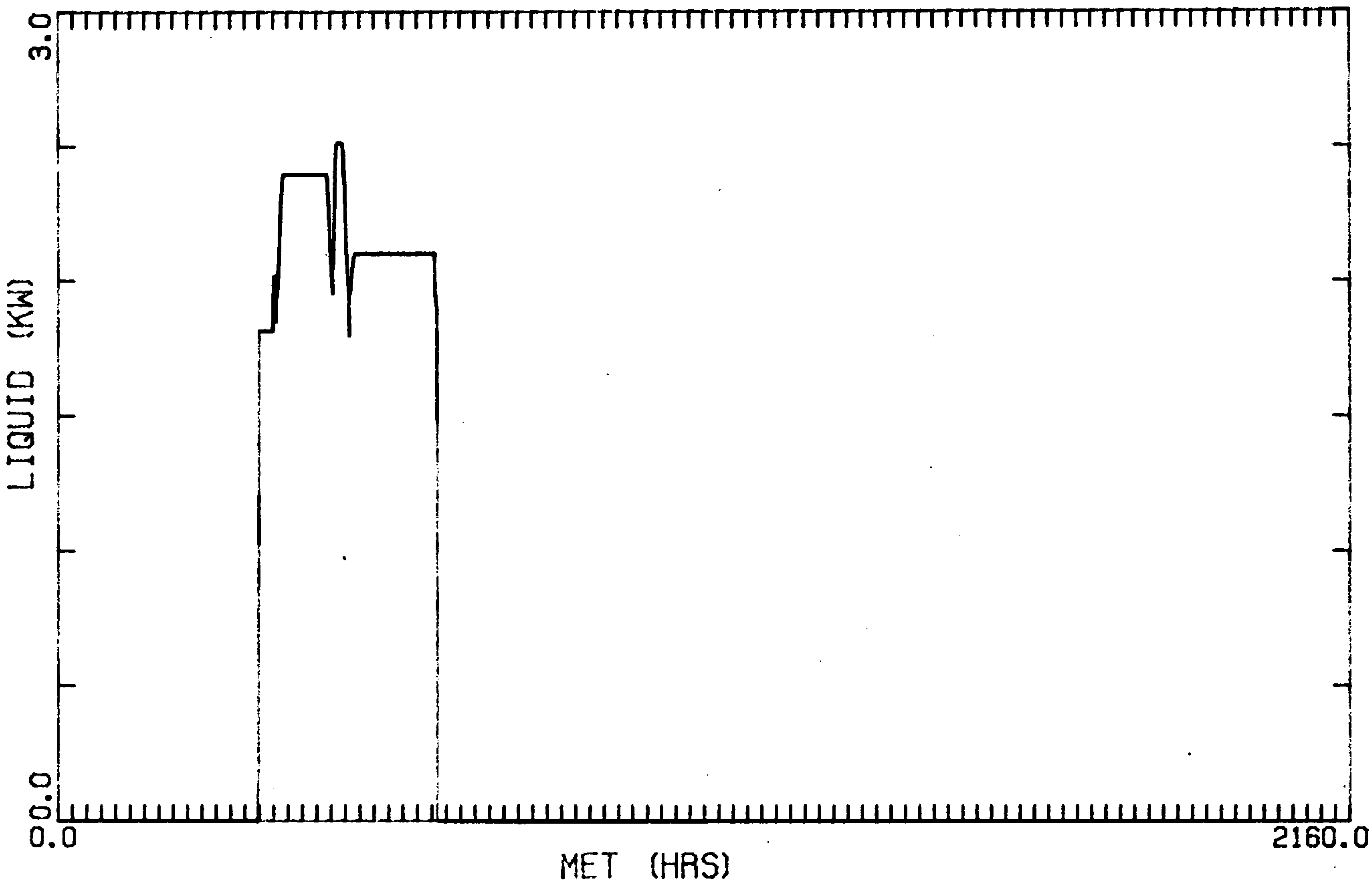
REQUESTED SHUTDOWN



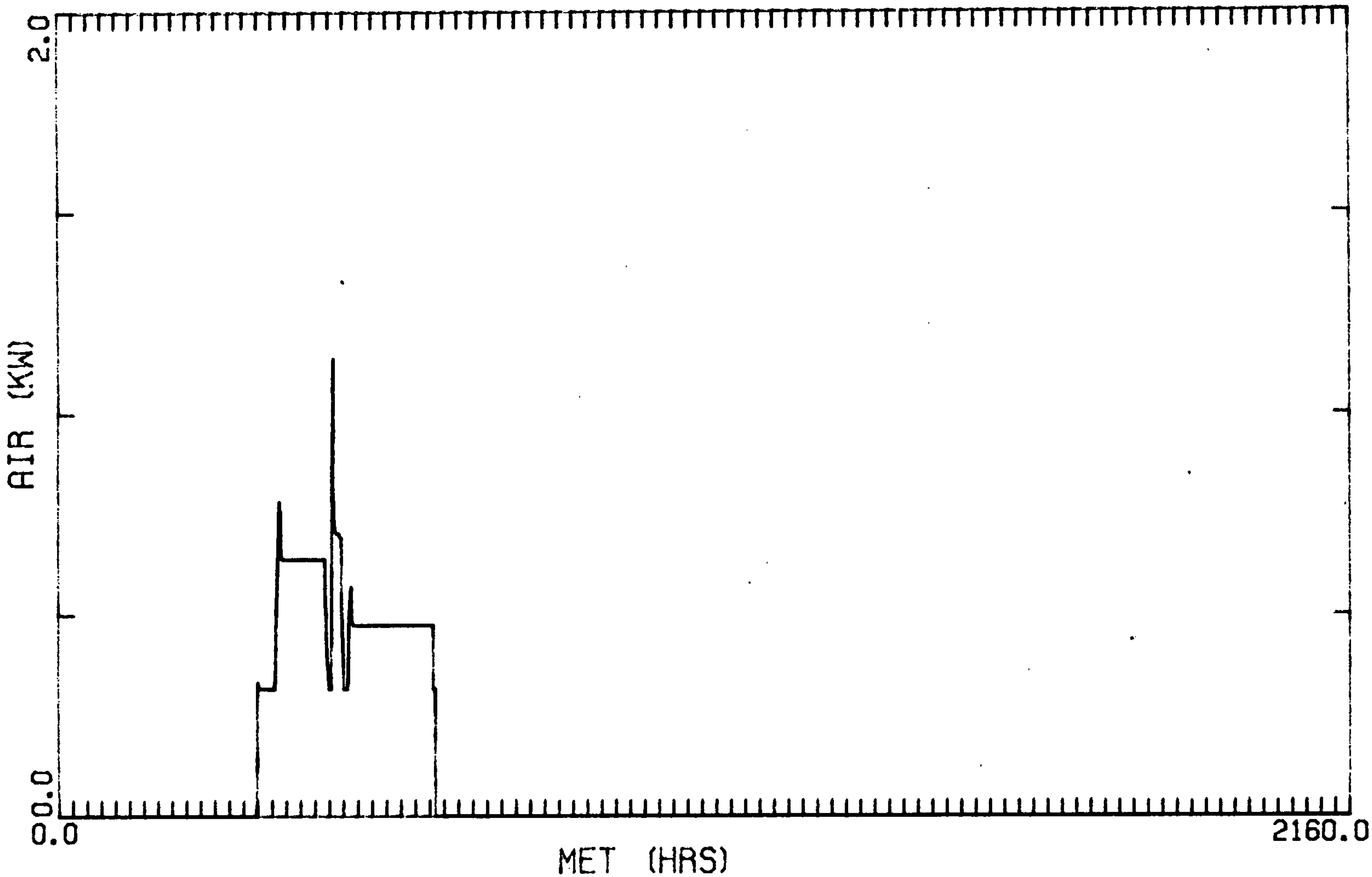
REQUESTED SHUTDØWN



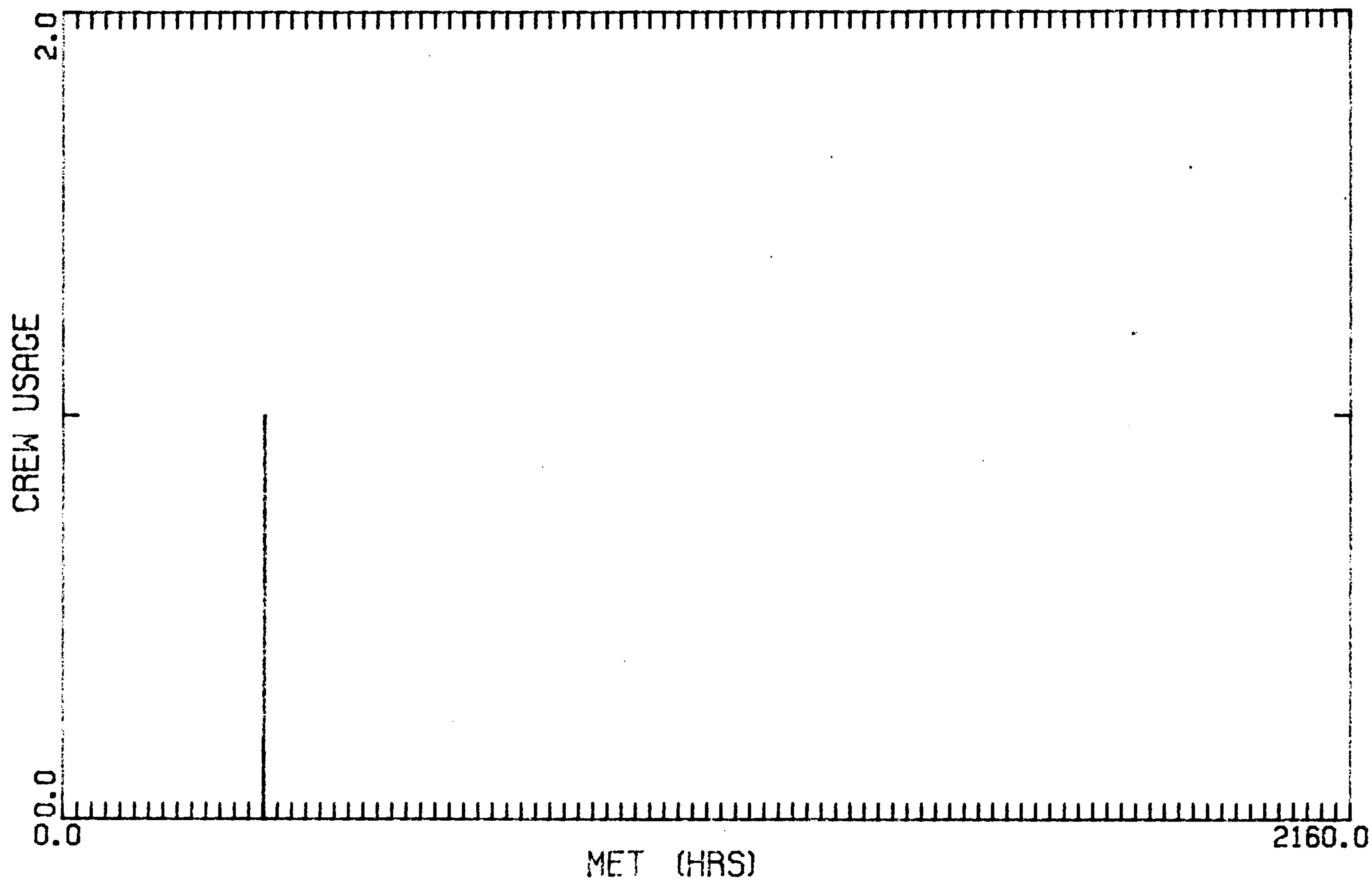
REQUESTED SHUTDØWN



REQUESTED SHUTDOWN



REQUESTED SHUTDØWN



REQUESTED SHUTDOWN

```
MODEL CORE-ACT      INSERTED FROM   336.00 HRS TO   336.50 HRS
MODEL FURNACE-ACT   INSERTED FROM   336.50 HRS TO   336.95 HRS
MODEL MSE           INSERTED FROM   336.95 HRS TO   339.55 HRS
MODEL STANDBY       INSERTED FROM   339.55 HRS TO   360.10 HRS
MODEL BAKEOUT       INSERTED FROM   360.10 HRS TO   365.10 HRS
MODEL CGF-CdTe      INSERTED FROM   365.10 HRS TO   460.00 HRS
MODEL CGF-GaAs      INSERTED FROM   460.00 HRS TO   487.20 HRS
MODEL PURGE         INSERTED FROM   487.20 HRS TO   487.97 HRS
MODEL CGF-HgZnTe-A  INSERTED FROM   487.97 HRS TO   630.60 HRS
MODEL SSF-REQ-SD    INSERTED FROM   630.60 HRS TO   630.62 HRS
MODEL FURNACE-SD    INSERTED FROM   630.62 HRS TO   630.77 HRS
MODEL SSFF-SHUTDN   INSERTED FROM   630.77 HRS TO   631.00 HRS
```

```
**** MAXIMUM RES1-POWER    4.559 KW
**** MAXIMUM RES2-DATA GENERATION  100.000 KBPS
```

```
**** TOTAL ENERGY RES1=     798.56 KWH
**** TOTAL ENERGY RES2=    9073.80 KBPSH = 4083210 KBytes DATA VOLUME
GROUP  1 ENERGY RES1 =     798.56 RES2 =   9073.80 CREW TIME (M-Hr) =      2.07
GROUP  2 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP  3 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =      0.00
```

MAXIMUM NUMBER OF CREW =   1.000

AVG POWER SSFF = 2.707 KW

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT	1	1	100.00000000%
CGF-CdTe	1	1	100.00000000%
CGF-GaAs	1	1	100.00000000%
PURGE	1	1	100.00000000%
CGF-HgZnTe-A	0	INTERRUPTED	0.00000000%

SSF-REQ-SD	1	1	100.00000000%
FURNACE-SD	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

REQUESTED SHUTDOWN

**** MAXIMUM RES1-LIQUID 2.514 KW
**** MAXIMUM RES2-AIR 1.141 KW

**** TOTAL ENERGY RES1= 647.16 KWH
**** TOTAL ENERGY RES2= 151.99 KWH

GROUP 1 ENERGY RES1 =	647.16	RES2 =	151.99	CREW TIME (M-Hr)	=	0.00
GROUP 2 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 3 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 4 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 5 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 6 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 7 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 8 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 9 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 10 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 11 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 12 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 13 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 14 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 15 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 16 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 17 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 18 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 19 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00
GROUP 20 ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr)	=	0.00

NON-REQUESTED SHUTDOWN SCENARIO DESCRIPTION

Scenario #6 will demonstrate a possible procedure for equipment safing. The type of samples processed are the same as in scenario five. The scenario will include a SSFF shutdown procedure that occurs as the result of a loss of one power bus. This shutdown will occur before all of the samples can be processed.

NON-REQUESTED SHUTDOWN SCENARIO OVERVIEW

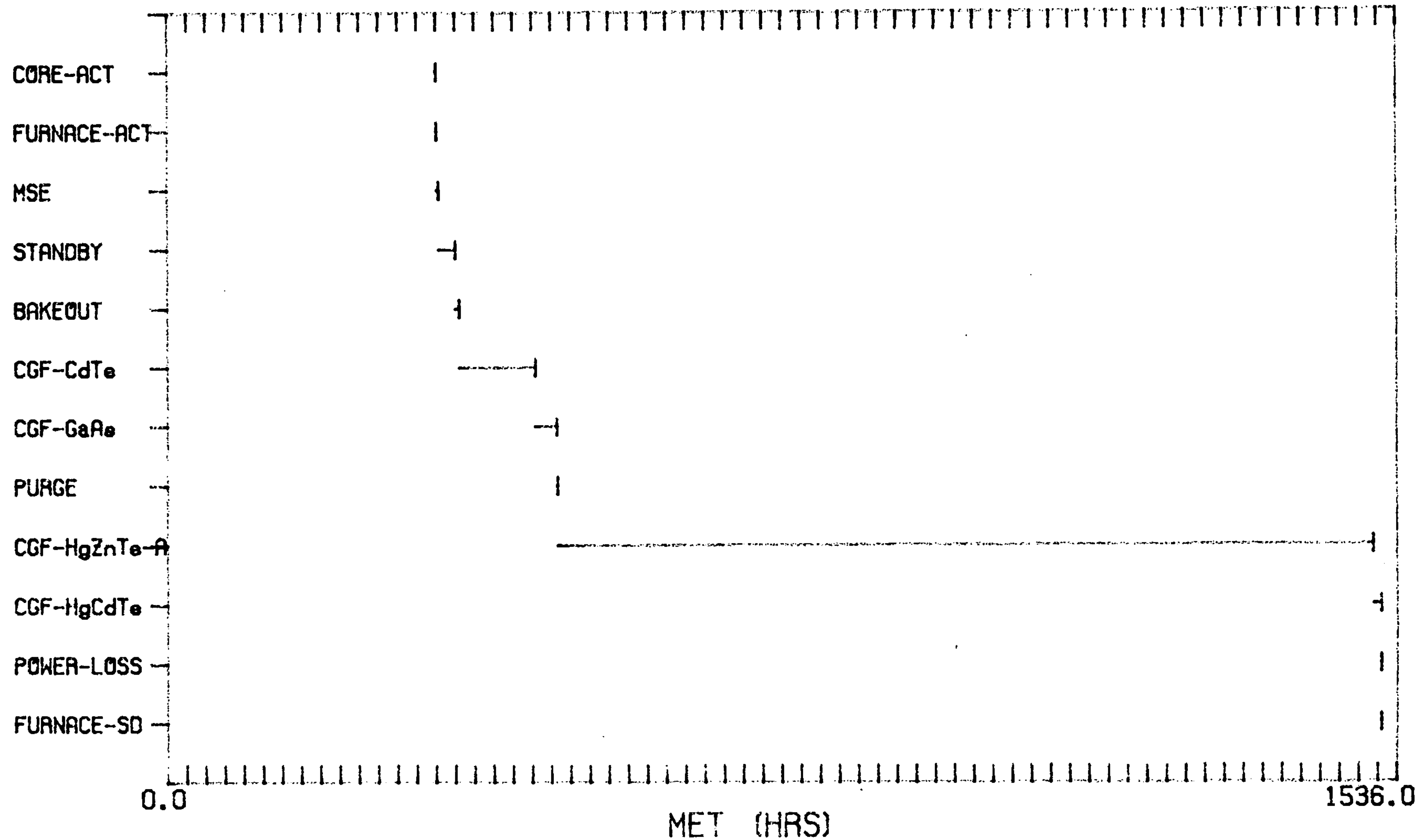
The operation of the SSFF in this scenario is as follows: Installation of the core rack and Furnace Module #1 occur on Utilization Flight TBD. The checkout of all hoses, lines, and equipment will be performed by the crew during Installation. Upon completion of the Installation stage, activation will occur. Activation occurs with the core equipment and distributed equipment respectively. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within the furnace rack. The Furnace Module is included in this activation step. After all the equipment is powered and allowed to warm-up, the SSFF reaches a standby mode. This Standby mode is when power consumption for subsystems are at normal operating amounts and the Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the Furnace Module is in a safe condition for crew interaction. After the samples are loaded in the Furnace Module, it is purged with Nitrogen. The furnace is then configured for a processing of samples. The configurement of the furnace depends on what sample is being processed. The furnace is vented of the nitrogen and filled with a processing gas. Argon is the processing gas in this scenario. At this point during Man-Tended Configuration the furnaces will remain at Standby mode until the crew leaves the SSF. Processing will occur upon crew departure from SSF to minimize vibrational disturbances. The time for completion of the activities listed above occur within the first 15 days of the 90 day mission. This will be the only time crew will be available for checkout of proper operation of systems and correction of any problems.

Upon crew departure a signal from the Core Control Unit (CCU) will allow for the Furnace Module to power up and start the processing cycle. The first sample to be processed is a calibration and bakeout sample. This sample calibrates the furnace at a predetermined time limit and proceeds with a bakeout of moisture for approximately 5 hours. Processing of two samples occurs next. They include CdTe and GaAs. Upon completion of processing a single sample the carousel within the furnace module will deliver a subsequent sample to be processed. A purge of

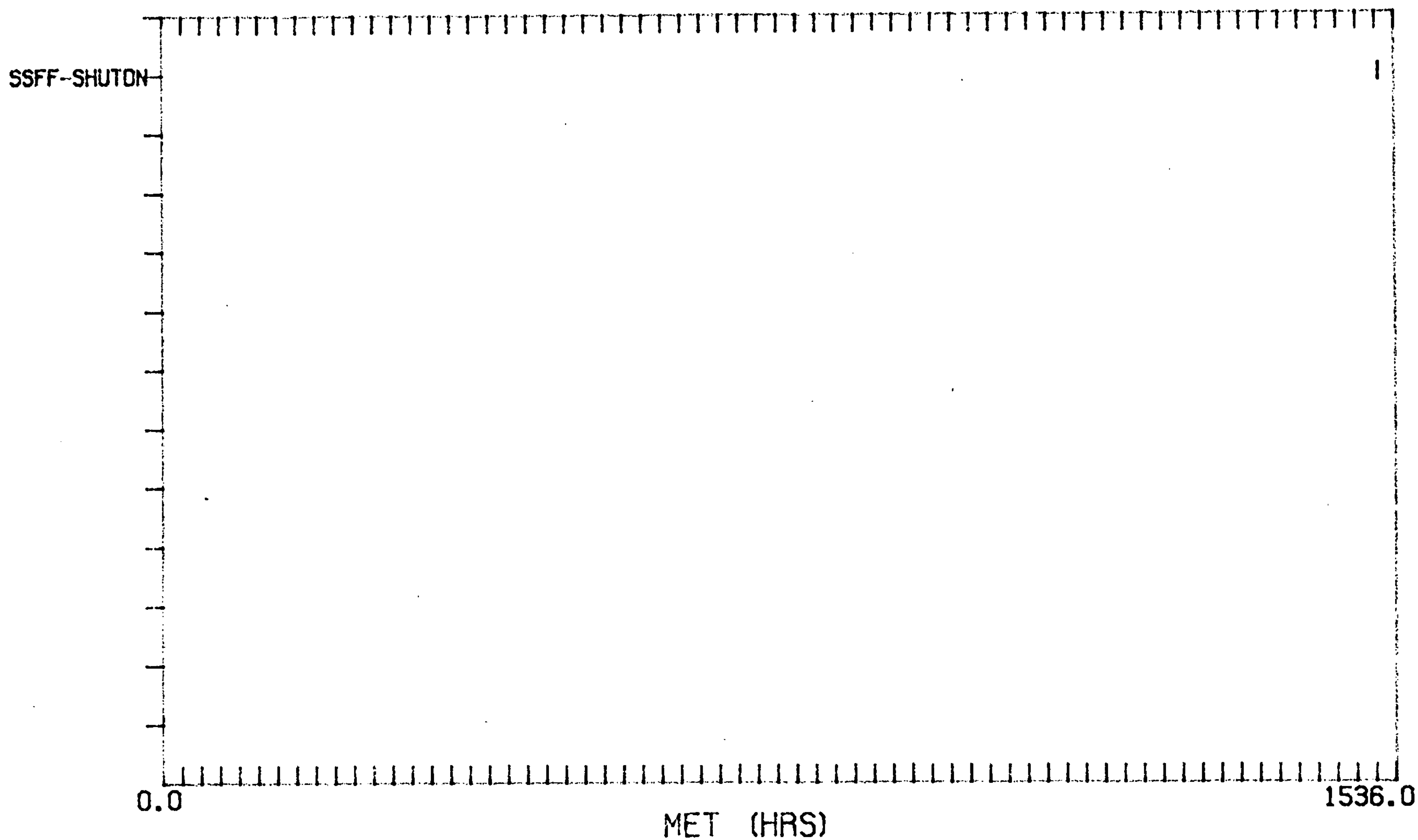
the furnace with fresh processing gas occurs after these three samples. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). An extended sample of HgZnTe is processed after a new supply of processing gas is contained within the furnace module. At approximately 10 hours into the processing of HgCdTe, a loss of one power bus occurs. The SSFF is capable of operation with the one remaining power bus, however because of safety requirements the shutdown procedure is implemented. After verifying only one power bus remains, the CCU immediately terminates power to the furnace module and the shutdown procedure begins. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration of SSFF requires the furnace to vent processing gas from the furnace module and to place the furnace into the home position. The TCS can be configured, for a short time, to aid in cooling the furnace module. The SSFF is capable of operating the essential equipment on one power bus, therefore the possibility remains that only essential equipment could continue to run and aid in monitoring and cooling of the Furnace Module.. This is dependent on SSF approval. If continued operation is denied, deactivation of the distributed equipment occurs followed by deactivation of the core equipment. In the shutdown of the core equipment, the TCS pump package and CCU will be the last components shutdown. Upon notification from the SSFF to suspend resources supplied by SSF, the Furnace Facility is completely shutdown.

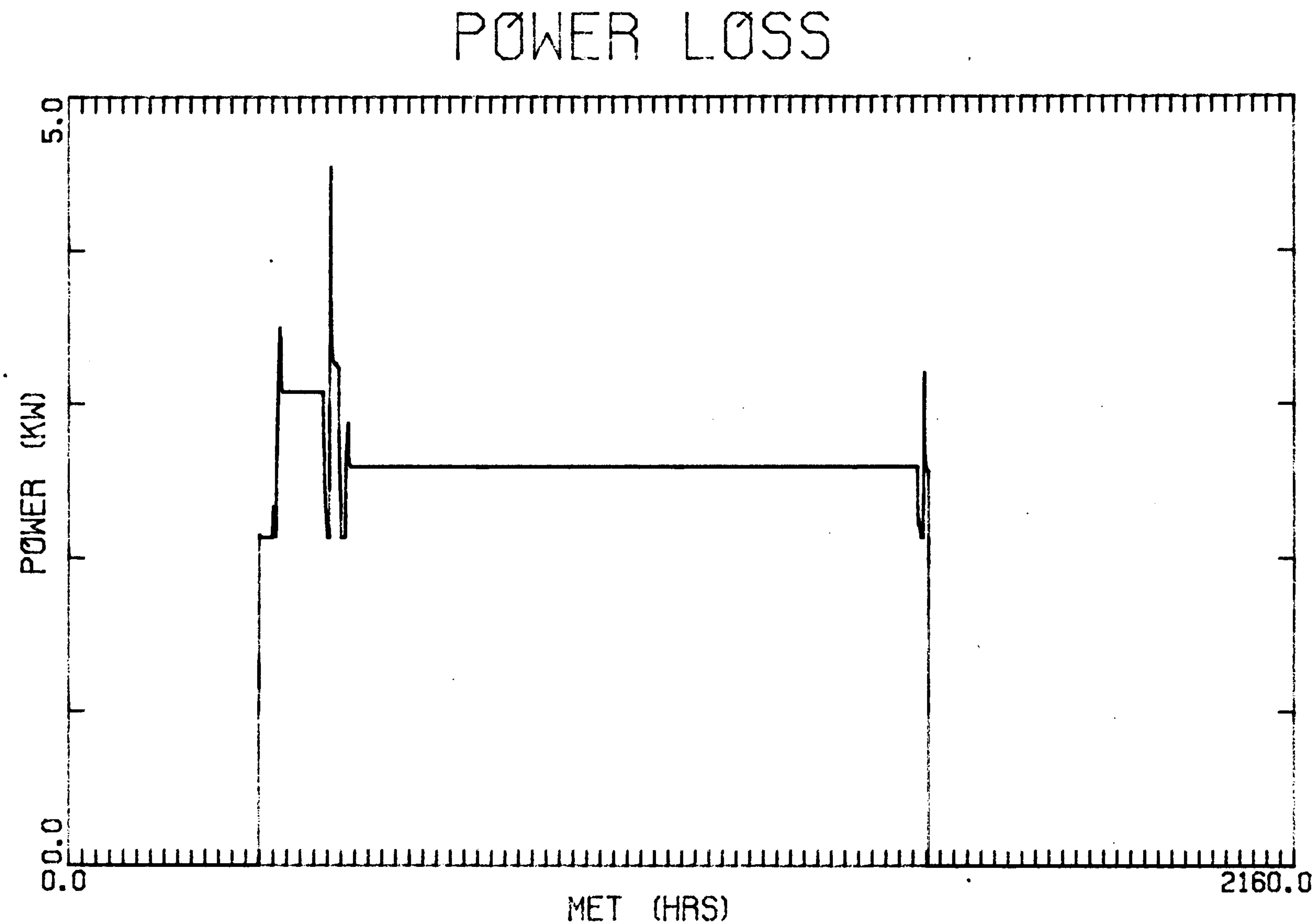
PØWER LØSS



CORE-ACT
FURNACE-ACT
MSE
STANDBY
BAKEOUT
CGF-CdTe
CGF-GaAs
PURGE
CGF-HgZnTe-A
CGF-HgCdTe
POWER-LOSS
FURNACE-SD
0.0
1536.0
MET (HRS)

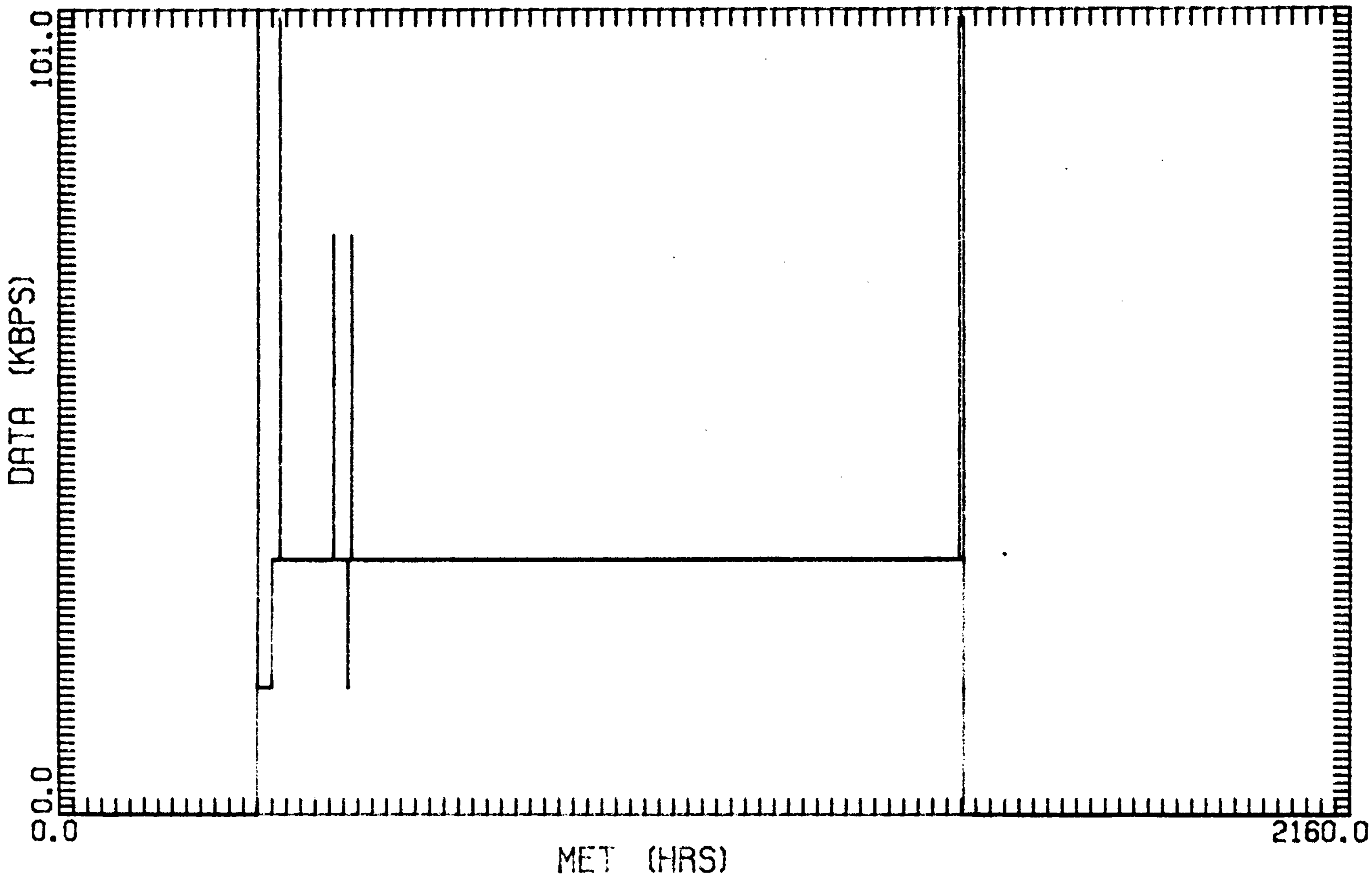
PØWER LØSS



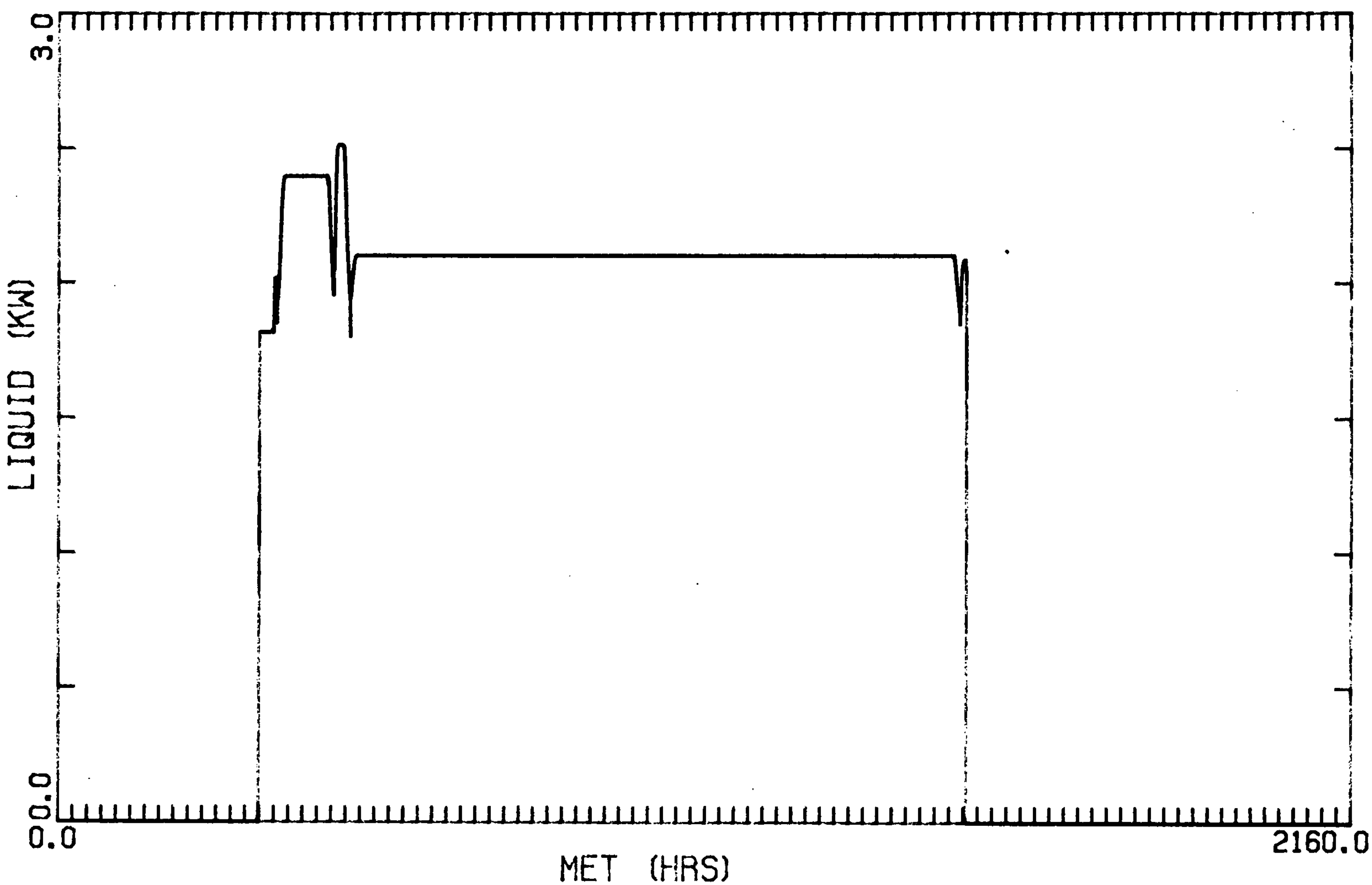


POWER LOSS
5.0
0.0
POWER (KW)
0.0
2160.0
MET (HRS)

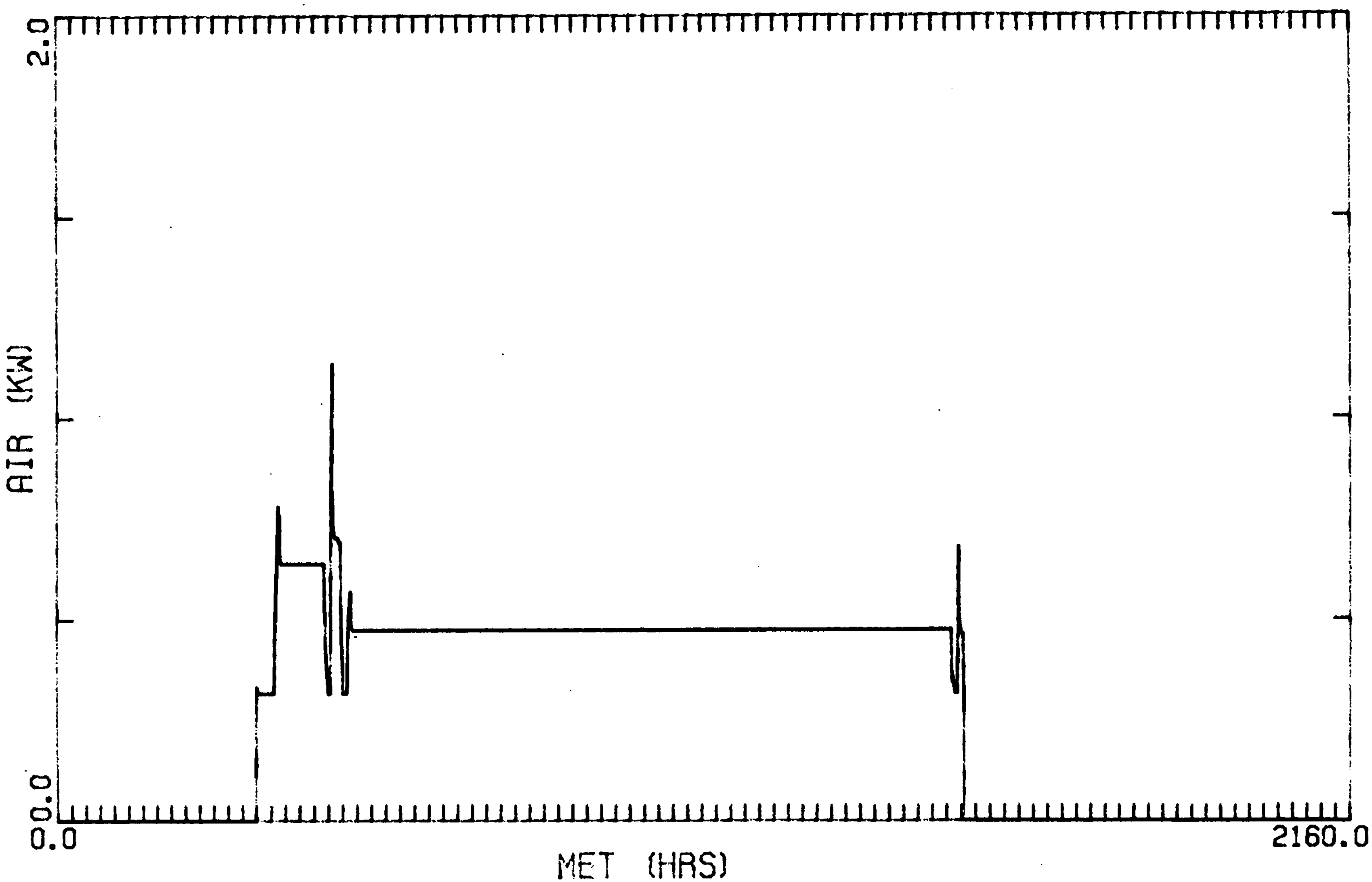
POWER LOSS

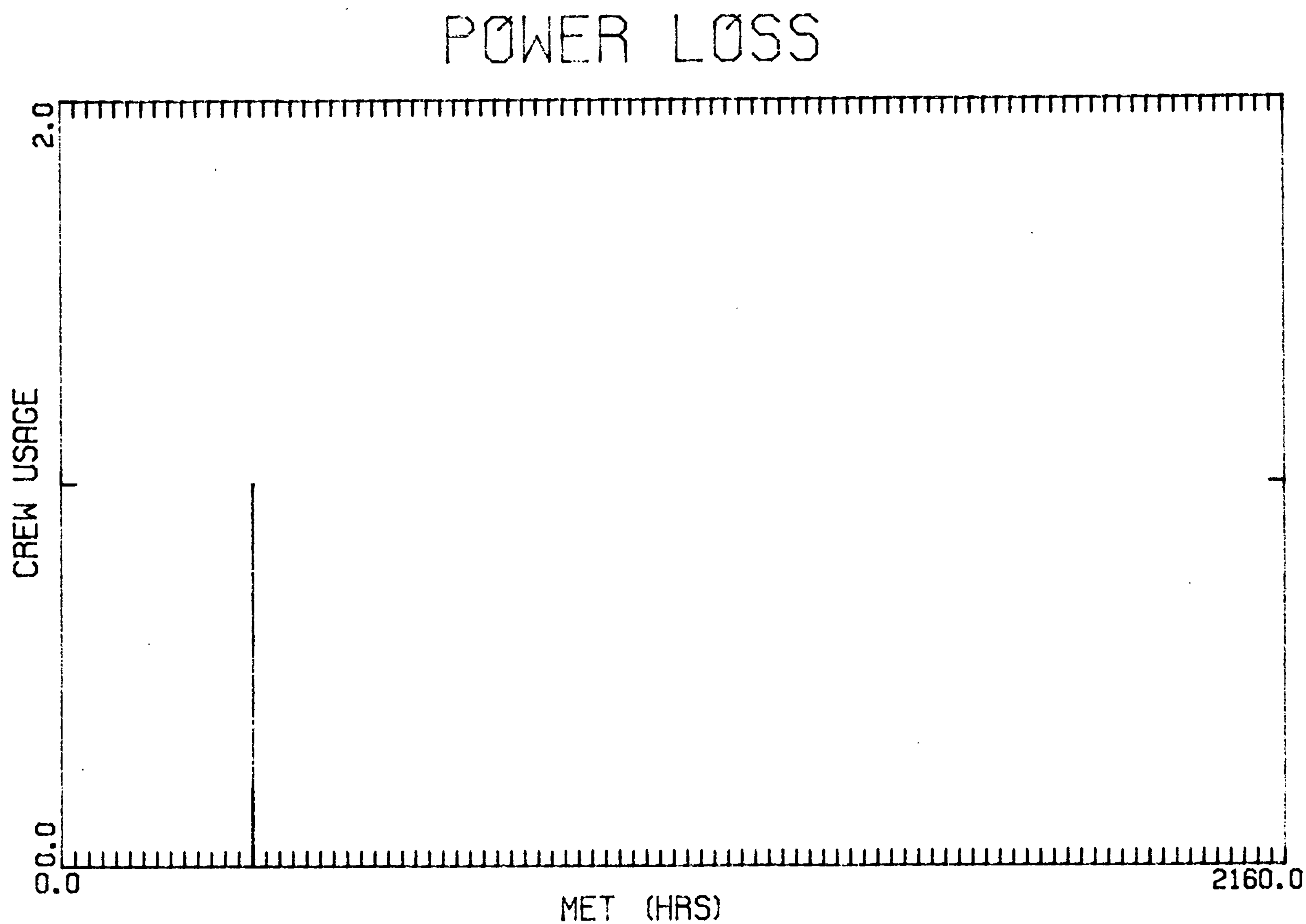


POWER LOSS



POWER LOSS




POWER LØSS
2.0
0.0
CREW USAGE
0.0
2160.0
MET (HRS)

POWER LOSS

```
MODEL CORE-ACT      INSERTED FROM   336.00 HRS TO   336.50 HRS
MODEL FURNACE-ACT   INSERTED FROM   336.50 HRS TO   336.95 HRS
MODEL MSE           INSERTED FROM   336.95 HRS TO   339.55 HRS
MODEL STANDBY       INSERTED FROM   339.55 HRS TO   360.10 HRS
MODEL BAKEOUT       INSERTED FROM   360.10 HRS TO   365.10 HRS
MODEL CGF-CdTe      INSERTED FROM   365.10 HRS TO   460.00 HRS
MODEL CGF-GaAs      INSERTED FROM   460.00 HRS TO   487.20 HRS
MODEL PURGE         INSERTED FROM   487.20 HRS TO   487.97 HRS
MODEL CGF-HgZnTe-A  INSERTED FROM   487.97 HRS TO  1506.55 HRS
MODEL CGF-HgCdTe    INSERTED FROM  1506.55 HRS TO  1516.22 HRS
MODEL POWER-LOSS    INSERTED FROM  1516.22 HRS TO  1516.23 HRS
MODEL FURNACE-SD    INSERTED FROM  1516.23 HRS TO  1516.38 HRS
MODEL SSFF-SHUTDN   INSERTED FROM  1516.38 HRS TO  1516.62 HRS

**** MAXIMUM RES1-    4.559 KW
**** MAXIMUM RES2-  100.000 KBPS

**** TOTAL ENERGY RES1=   3092.18 KWH
**** TOTAL ENERGY RES2=  37420.33 KBPSH = 16839148.5 KBytes DATA VOLUME
GROUP  1 ENERGY RES1 =  3092.18 RES2 =  37420.34 CREW TIME (M-Hr) =    2.07
GROUP  2 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP  3 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP  4 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP  5 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP  6 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP  7 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP  8 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP  9 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 10 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 11 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 12 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 13 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 14 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 15 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 16 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 17 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 18 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 19 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00
GROUP 20 ENERGY RES1 =     0.00 RES2 =      0.00 CREW TIME (M-Hr) =    0.00

MAXIMUM NUMBER OF CREW =    1.000

AVG POWER SSFF = 2.6191

EXPERIMENTS         NO.RUNS  DESIRED RUNS  PERCENTAGE
CORE-ACT               1          1       100.00000000%
FURNACE-ACT            1          1       100.00000000%
MSE                    1          1       100.00000000%
STANDBY                1          1       100.00000000%
BAKEOUT                1          1       100.00000000%
CGF-CdTe               1          1       100.00000000%
CGF-GaAs               1          1       100.00000000%
PURGE                  1          1       100.00000000%
```

CGF-HgZnTe-A	1	1	100.00000000%
CGF-HgCdTe	0	INTERRUPTED	0.00000000%
POWER-LOSS	1	1	100.00000000%
FURNACE-SD	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

POWER LOSS

**** MAXIMUM RES1-LIQUID 2.514 KW
**** MAXIMUM RES2-AIR 1.141 KW

**** TOTAL ENERGY RES1= 2501.54 KWH
**** TOTAL ENERGY RES2= 568.80 KWH

GROUP 1	ENERGY RES1 =	2501.54	RES2 =	568.80	CREW TIME (M-Hr) = 0.00
GROUP 2	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 3	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00

PROGRAMMING TASK DESCRIPTION

Scenario #7 displays a delayed time increment for the possible reprogramming of furnace parameters. The reprogramming task occurs after completion of the second sample. The SSFF remains in standby during a 20 minute delay for reprogramming of the processing parameters. The type of samples processed are again the same as in Scenario #5.

PROGRAMMING TASK SCENARIO OVERVIEW

The operation of the SSFF in this scenario is as follows: Installation of the core rack and Furnace Module #1 occur on Utilization Flight TBD. The checkout of all hoses, lines, and equipment will be performed by the crew during Installation. Upon completion of the Installation stage, activation will occur. Activation occurs with the core equipment and distributed equipment respectively. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within the furnace rack. The Furnace Module is included in this activation step. After all the equipment is powered and allowed to warm-up, the SSFF reaches a standby mode. This Standby mode is when power consumption for subsystems are at normal operating amounts and the Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

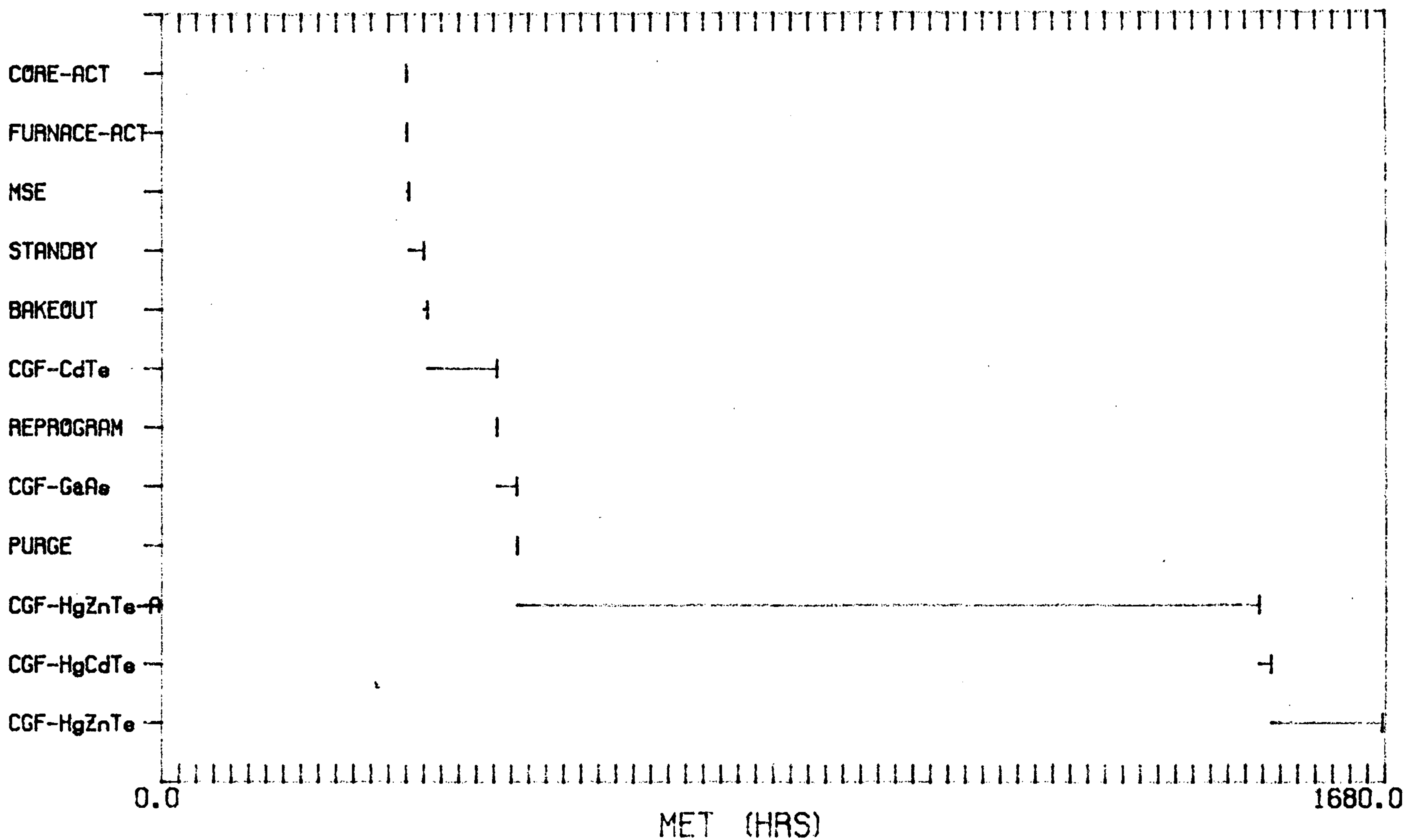
Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the Furnace Module is in a safe condition for crew interaction. After the samples are loaded in the Furnace Module, it is purged with Nitrogen. The furnace is then configured for a processing of samples. The configurement of the furnace depends on what sample is being processed. The furnace is vented of the nitrogen and filled with a processing gas. Argon is the processing gas in this scenario. At this point during Man-Tended Configuration the furnaces will remain at Standby mode until the crew leaves the SSF. Processing will occur upon crew departure from SSF to minimize vibrational disturbances. The time for completion of the activities listed above occur within the first 15 days of the 90 day mission. This will be the only time crew will be available for checkout of proper operation of systems and correction of any problems.

Upon crew departure a signal from the Core Control Unit (CCU) will allow for the Furnace Module to power up and start the processing cycle. The first sample to be processed is a calibration and bakeout sample. This sample calibrates the furnace at a predetermined time limit and proceeds with a bakeout of moisture for approximately 5 hours. Processing of two samples occurs next. They include CdTe and GaAs. After CdTe is processed, a parameter change is

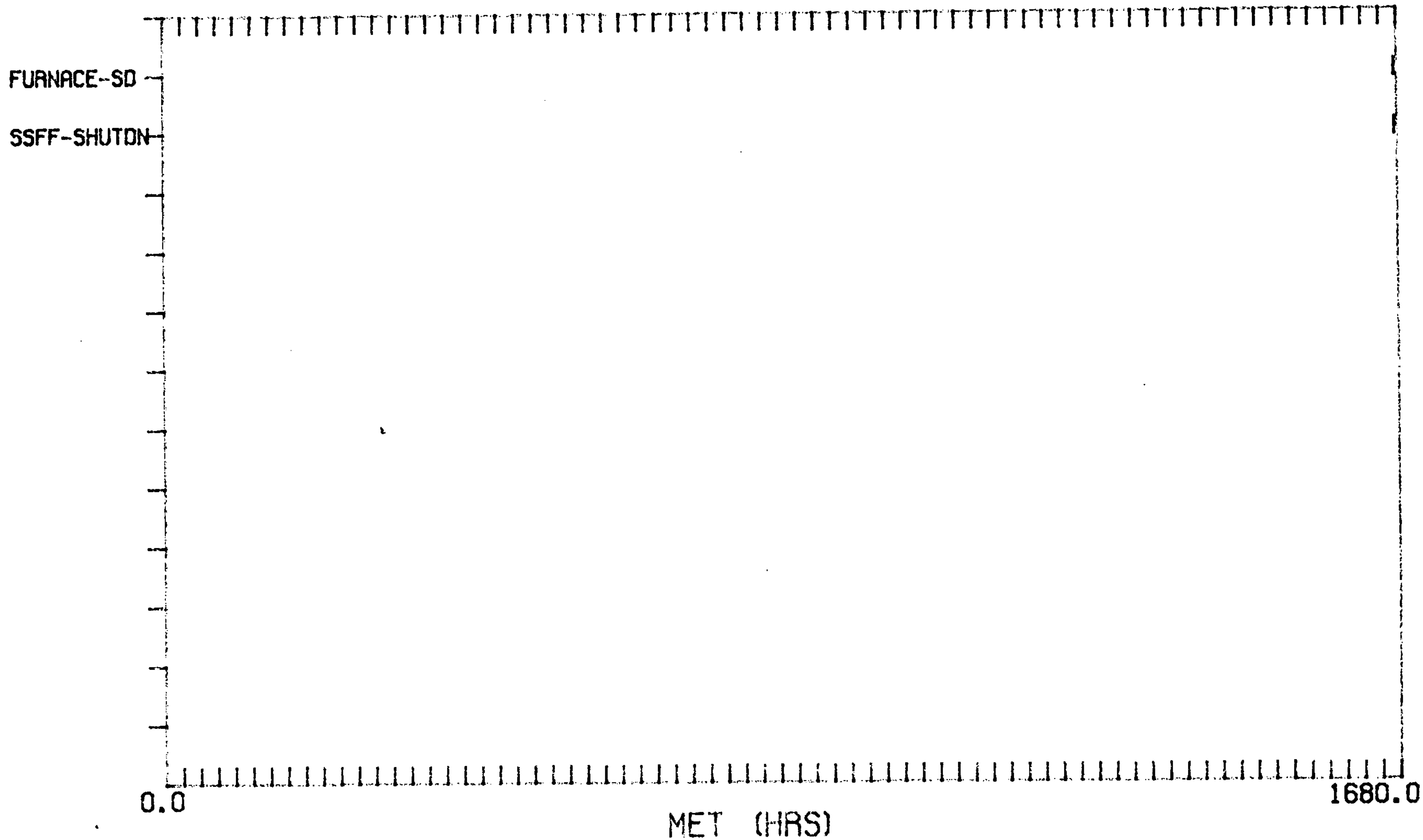
initiated from the DMS. The Furnace Facility remains in a standby mode while this occurs. The delay for a reprogramming task is dependent on the ability to uplink information. In modeling this scenario reprogramming time was assumed to take approximately 20 minutes. Upon completion of processing a single sample the carousel within the furnace module will deliver a subsequent sample to be processed. A purge of the furnace with fresh processing gas occurs after these three samples. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). An extended sample of HgZnTe is processed after a new supply of processing gas is contained within the furnace module. The remaining samples include HgCdTe and HgZnTe. Upon completion of the entire carousel of samples the furnace is returned to a standby mode.From the standby mode complete shutdown can occur.

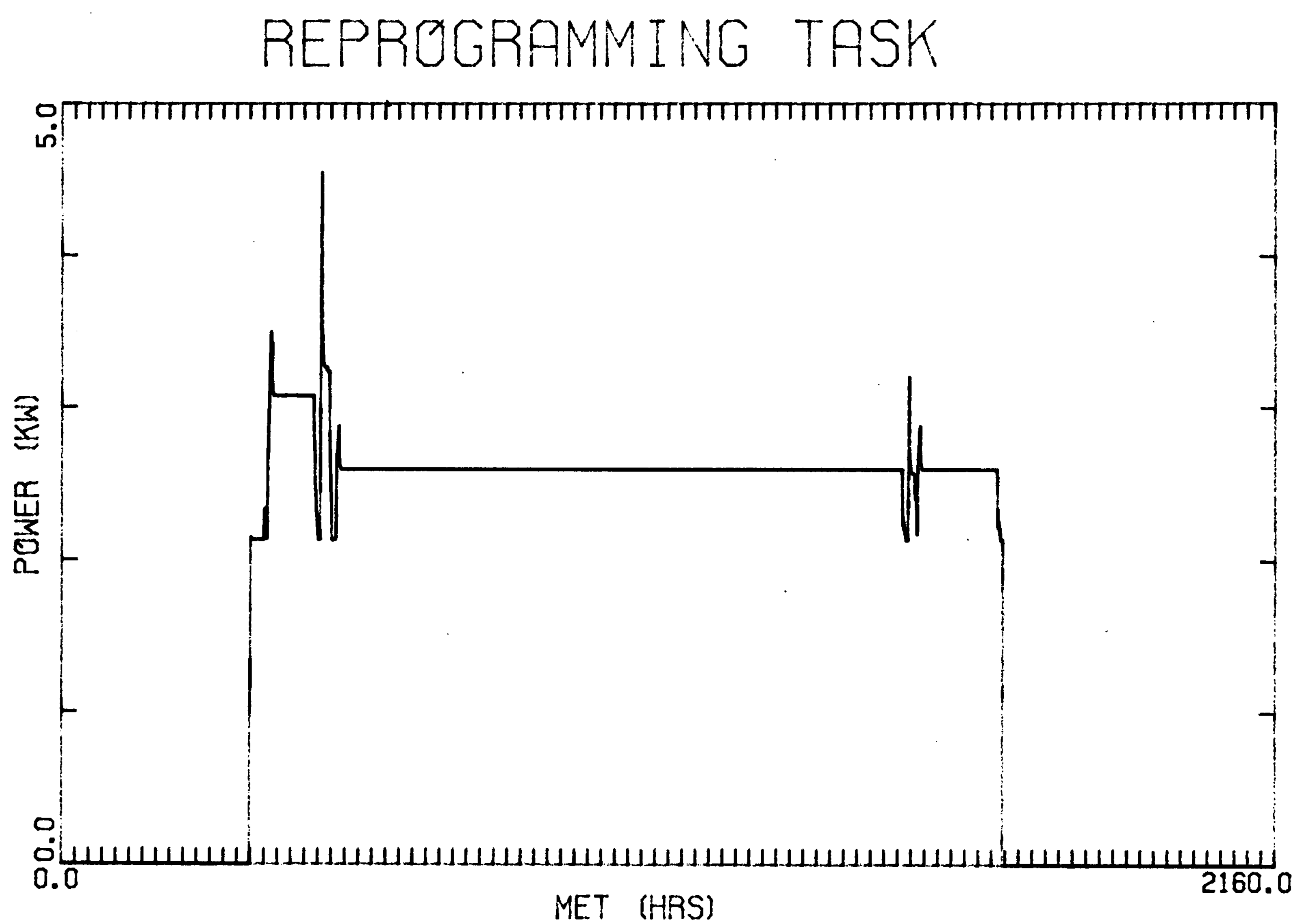
Shutdown occurs through a process of: reconfiguration of the SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration is required to vent the furnace of processing gas, configure the TCS into the core rack, and check that the furnace is in the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

REPRØGRAMMING TASK

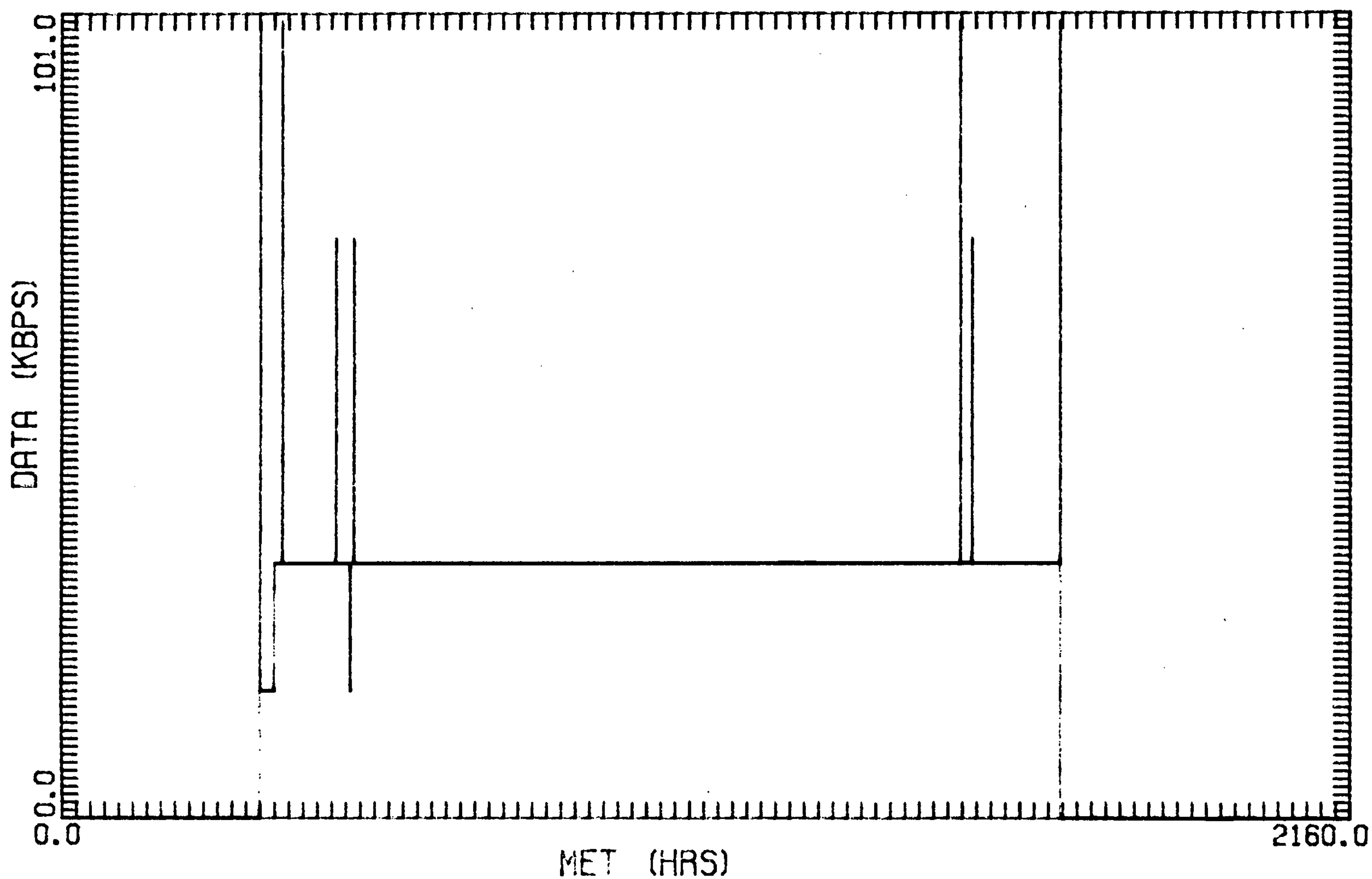


REPRØGRAMMING TASK

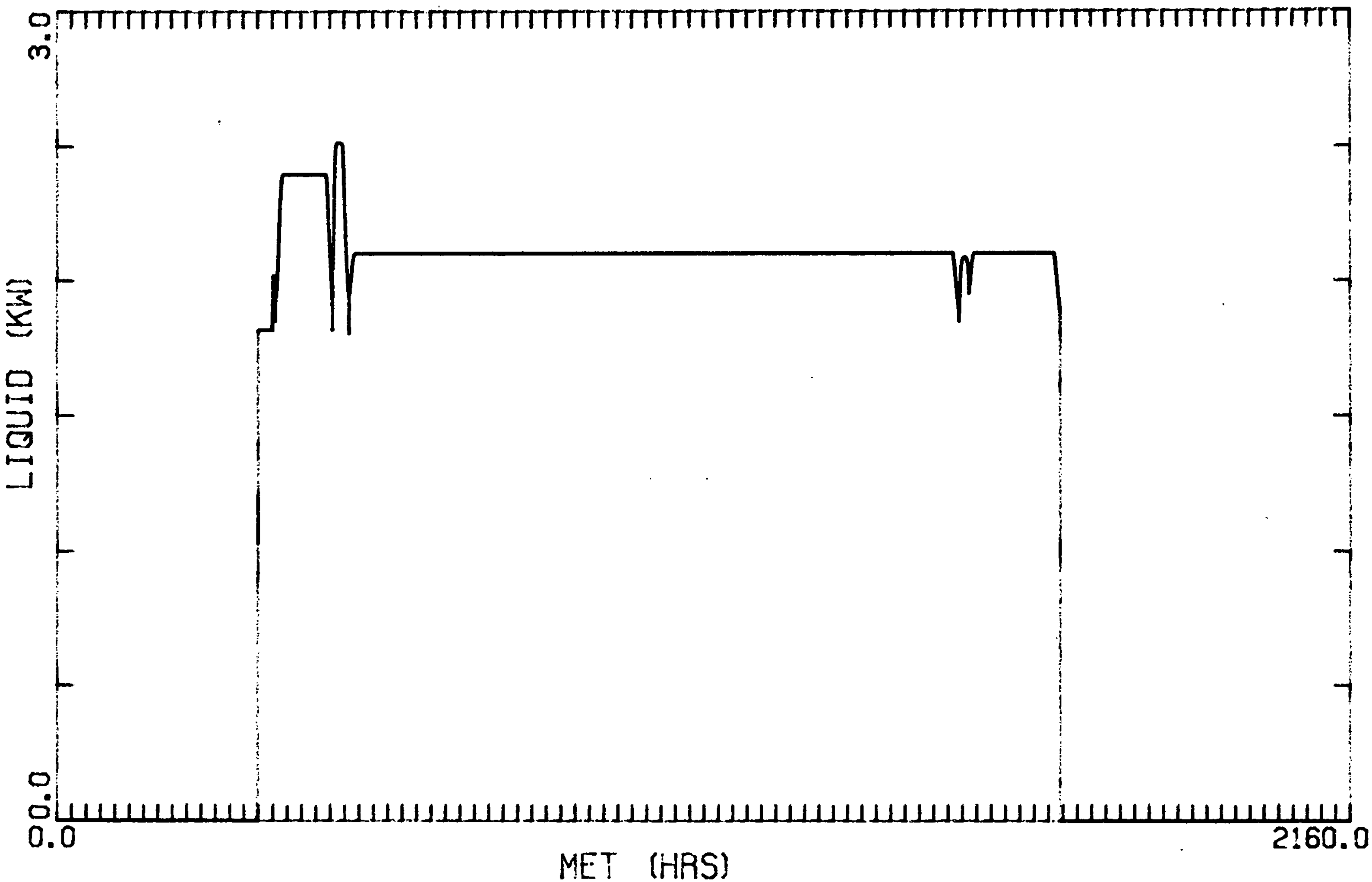



REPRØGRAMMING TASK
POWER (KW)
5.0
0.0
0.0
2160.0
MET (HRS)

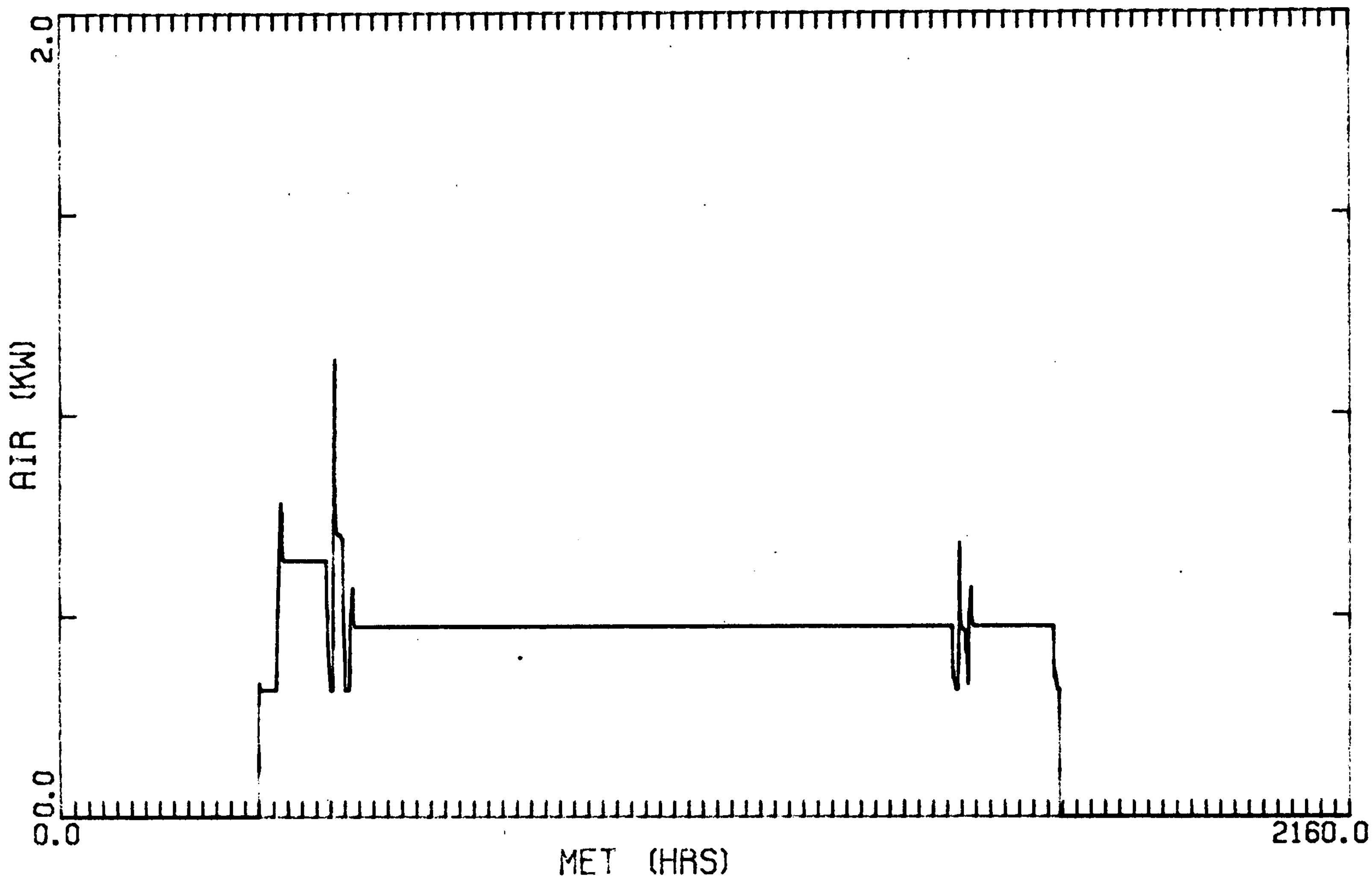
REPRØGRAMMING TASK



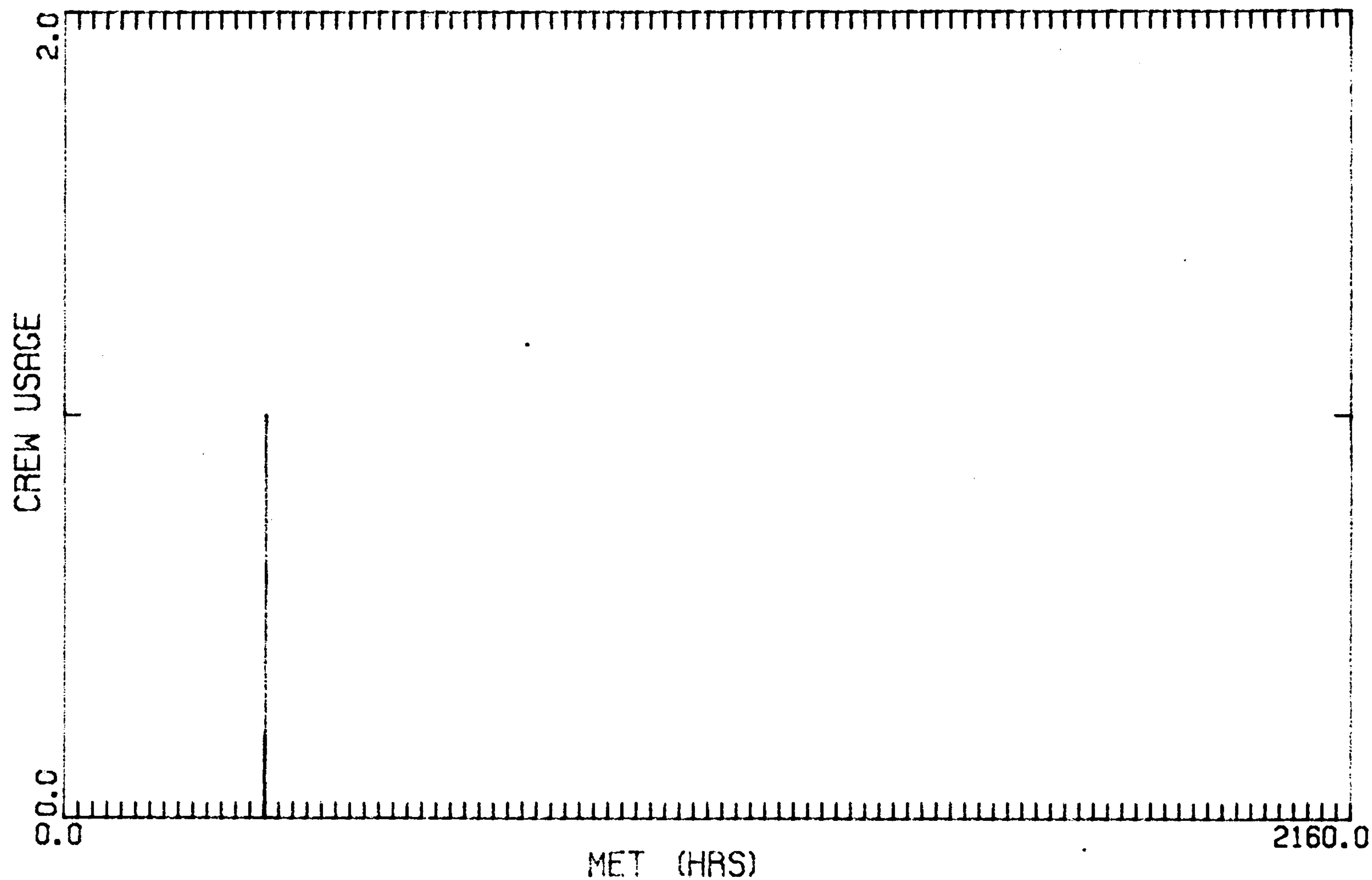
REPRØGRAMMING TASK



REPRØGRAMMING TASK



REPRØGRAMMING TASK



REPROGRAMMING TASK

MODEL	CORE-ACT	INSERTED FROM	336.00	HRS	TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED FROM	336.50	HRS	TO	336.95	HRS
MODEL	MSE	INSERTED FROM	336.95	HRS	TO	339.55	HRS
MODEL	STANDBY	INSERTED FROM	339.55	HRS	TO	360.10	HRS
MODEL	BAKEOUT	INSERTED FROM	360.10	HRS	TO	365.10	HRS
MODEL	CGF-CdTe	INSERTED FROM	365.10	HRS	TO	460.00	HRS
MODEL	REPROGRAM	INSERTED FROM	460.00	HRS	TO	460.33	HRS
MODEL	CGF-GaAs	INSERTED FROM	460.33	HRS	TO	487.53	HRS
MODEL	PURGE	INSERTED FROM	487.53	HRS	TO	488.30	HRS
MODEL	CGF-HgZnTe-A	INSERTED FROM	488.30	HRS	TO	1506.88	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1506.88	HRS	TO	1523.38	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	1523.38	HRS	TO	1676.08	HRS
MODEL	FURNACE-SD	INSERTED FROM	1676.08	HRS	TO	1676.23	HRS
MODEL	SSFF-SHUTDN	INSERTED FROM	1676.23	HRS	TO	1676.47	HRS

**** MAXIMUM RES1-POWER 4.559 KW
**** MAXIMUM RES2-DATA GENERATION 100.000 KBPS

**** TOTAL ENERGY RES1= 3502.33 KWH
**** TOTAL ENERGY RES2= 42542.87 KBPSH = 19144292 KBytes DATA VOLUME

GROUP 1	ENERGY RES1 = 3502.33	RES2 = 42542.87	CREW TIME (M-Hr) =	2.07
GROUP 2	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 3	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 4	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 5	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 6	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 7	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 8	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 9	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 10	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 11	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 12	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 13	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 14	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 15	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 16	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 17	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 18	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 19	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 20	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 2.617

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT	1	1	100.00000000%
CGF-CdTe	1	1	100.00000000%
REPROGRAM	1	1	100.00000000%

CGF-GaAs	1	1	100.00000000%
PURGE	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe	1	1	100.00000000%
FURNACE-SD	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

REPROGRAMMING TASK

```
**** MAXIMUM RES1-LIQUID     2.514 KW
**** MAXIMUM RES2-AIR        1.141 KW


**** TOTAL ENERGY RES1=    2831.71 KWH
**** TOTAL ENERGY RES2=     642.32 KWH
GROUP  1 ENERGY RES1 =    2831.71 RES2 =     642.32 CREW TIME (M-Hr) =       0.00
GROUP  2 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  3 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
```

PMC BASELINE SCENARIO DESCRIPTION

The eighth scenario is used as a baseline to demonstrate normal SSFF operations with two furnaces. The first sample in each furnace is a characterization sample. The remaining five samples are HgCdTe, HgZnTe, GaAs, CdTe, and HgZnTe. HgZnTe is repeated in both furnaces to demonstrate typical operations using a six sample carousel. Once the initial six samples have been processed, the crew will load the furnaces with another six samples to utilize an entire 90 day mission.

PMC BASELINE SCENARIO OVERVIEW

The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

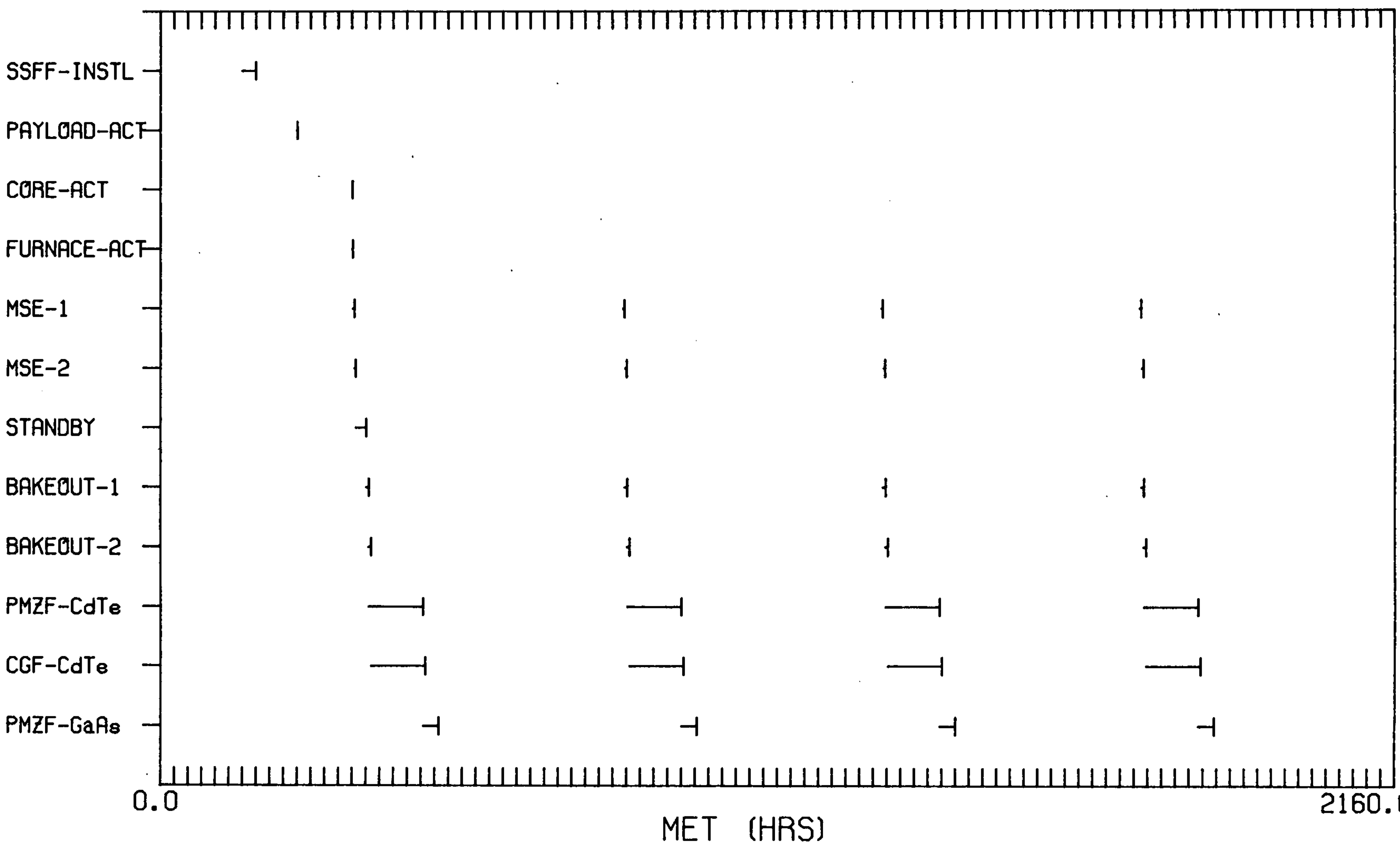
Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Until the time when resources are allocated for processing, the SSFF will remain in a standby mode. When resources are secured, samples may be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of the system and correct any problems.

A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a

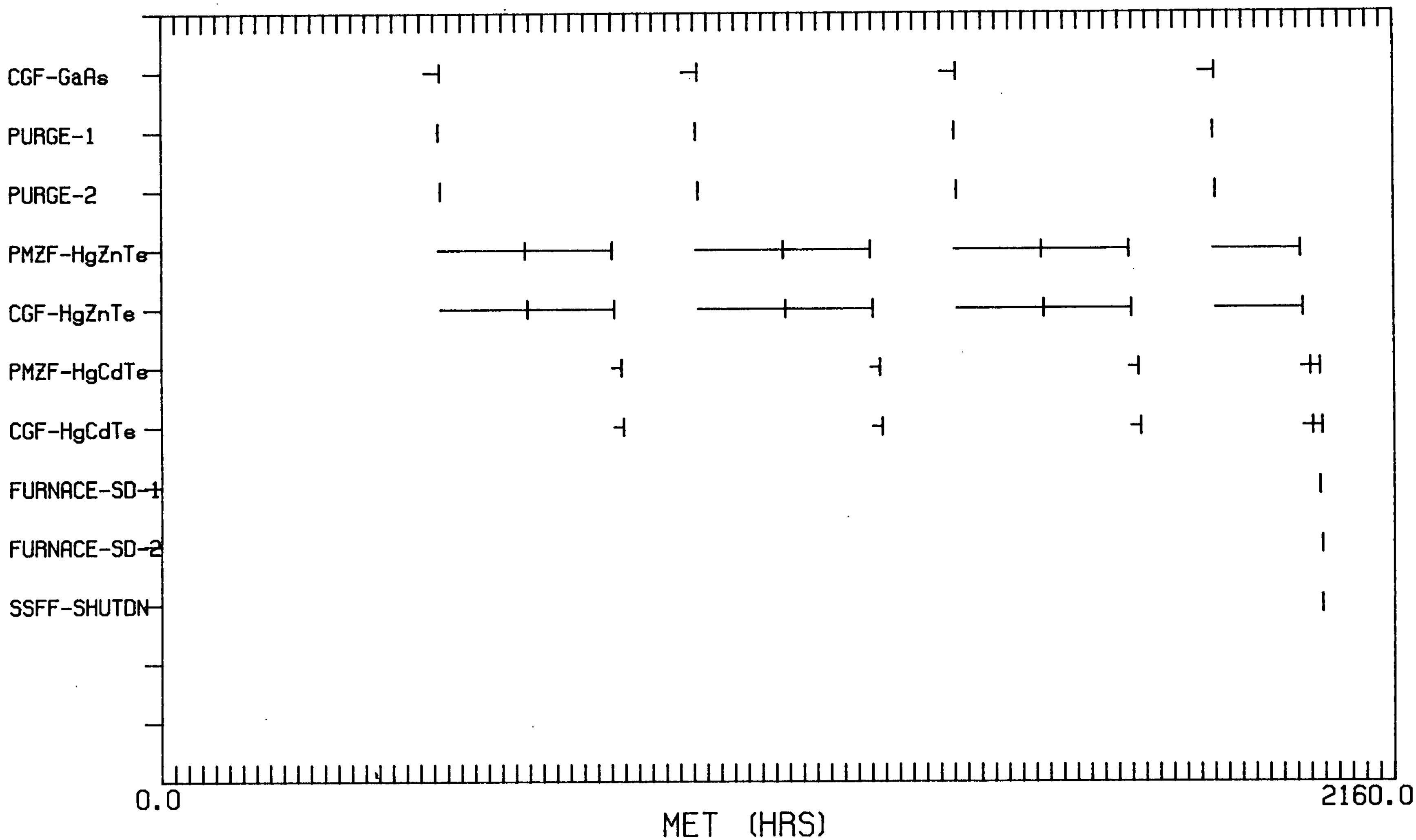
predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples occurs next. The samples include CdTe and GaAs. Upon completion of processing a single sample the carousel within the furnace module will deliver a subsequent sample to be processed. Purging of both furnace modules occurs after the first three samples in the scenario described. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). Two samples of HgZnTe and a sample HgCdTe are processed within the furnace modules. Upon completion of the entire carousel of samples the Furnace Modules are returned to a standby mode.

From the standby mode complete shutdown can occur, however with crew available in PMC samples may be exchanged. From the standby mode, the manual sample exchange can be utilized and another set of samples loaded. The process continues as before processing carousels of samples in each furnace module. The cycle continues with an option to shutdown either Furnace Module after every completed carousel. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration requires the furnace to vent processing gas from the furnace, configure the TCS into the core rack, and place the furnace into the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

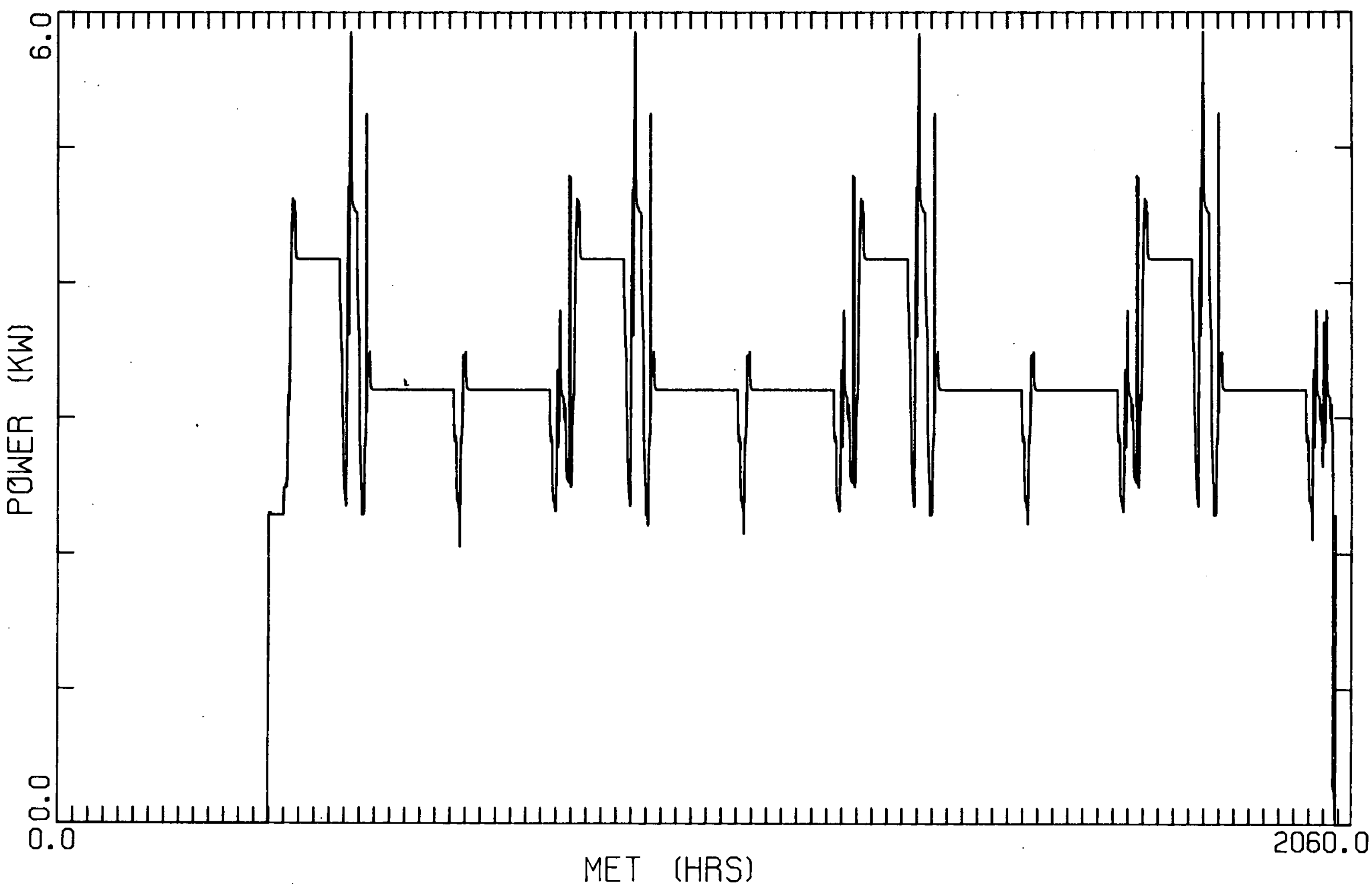
PMC BASELINE



PMC BASELINE



PMC BASELINE



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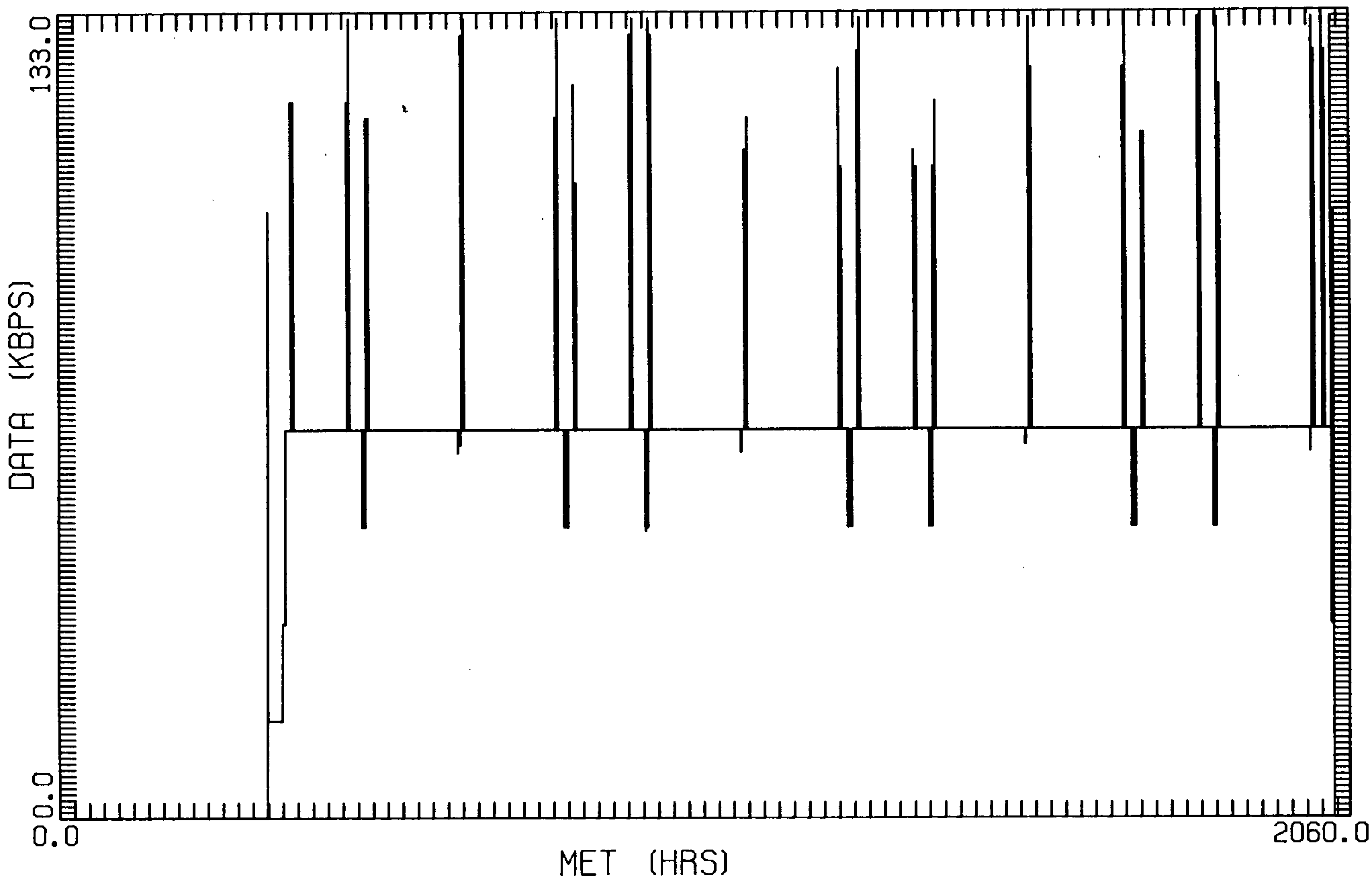
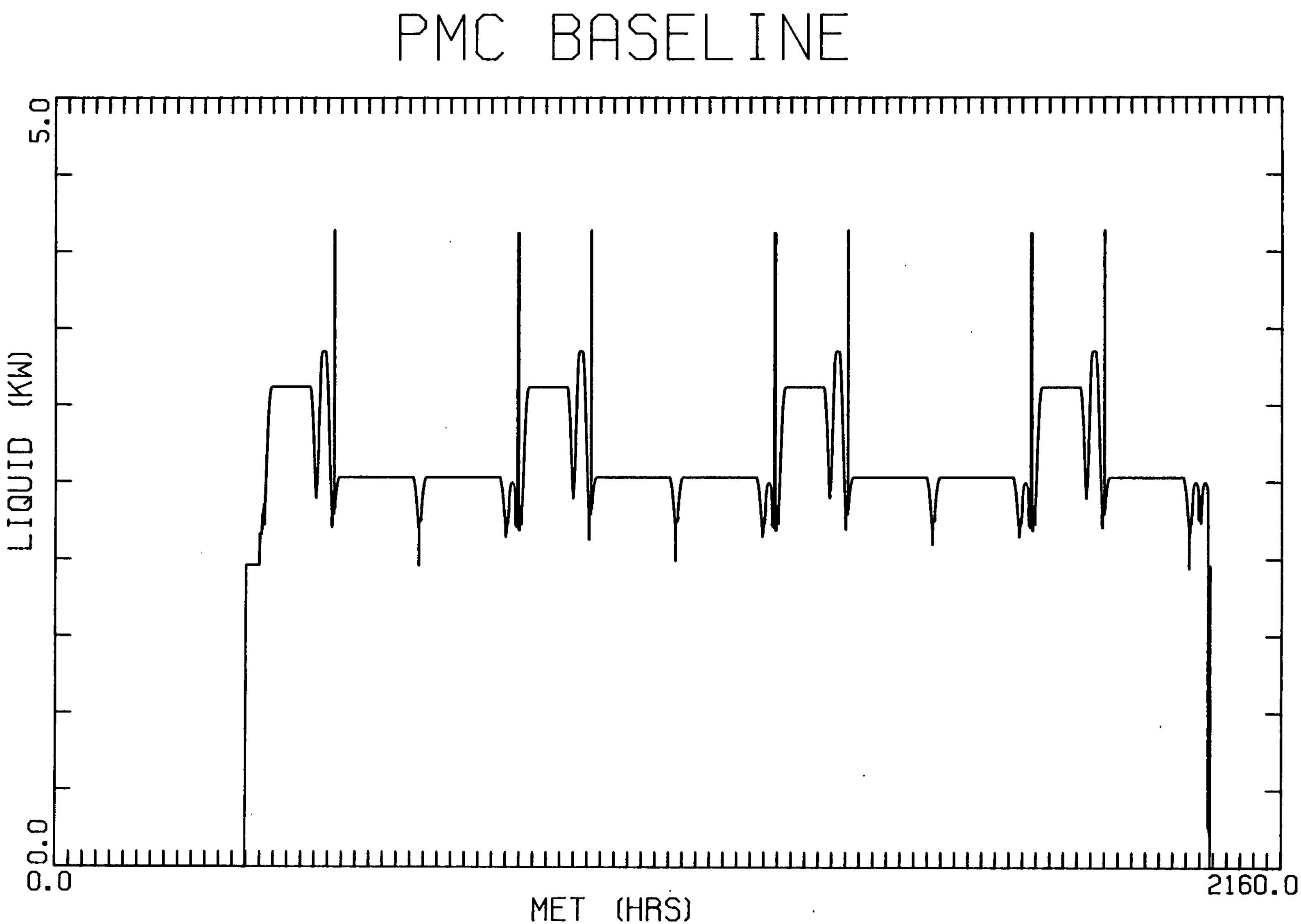
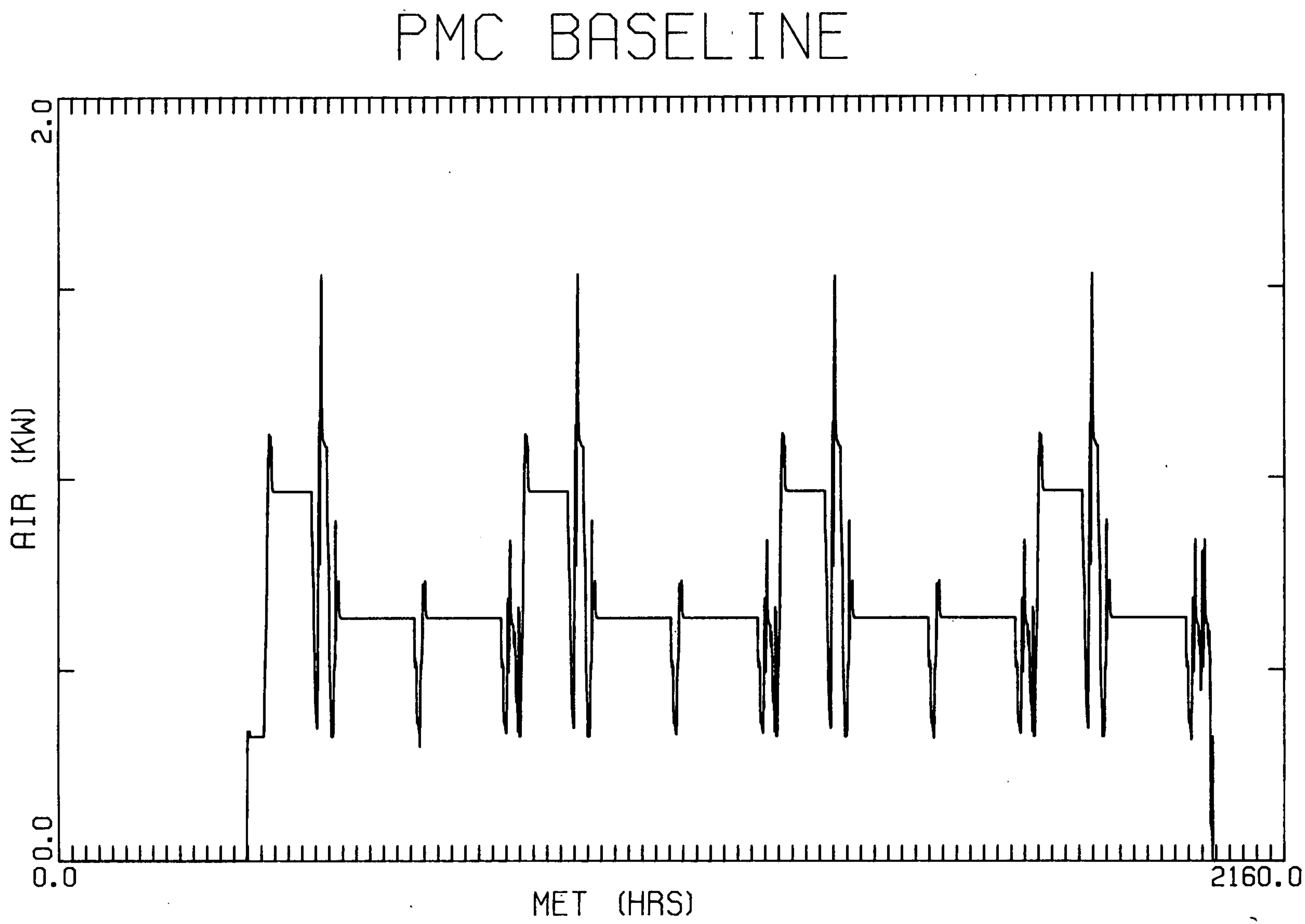
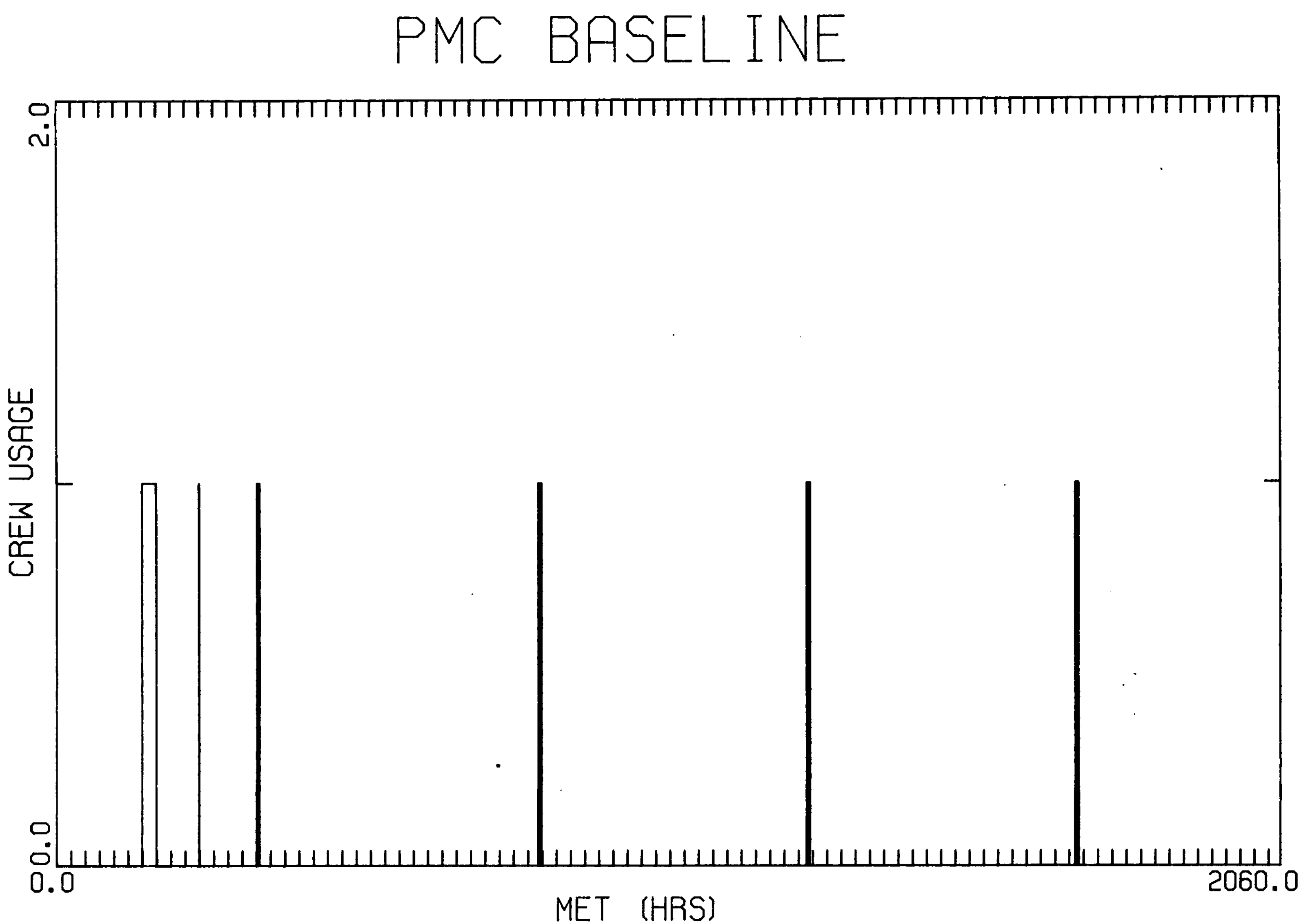



PMC BASELINE
5.0
LIQUID (KW)
0.0
0.0
MET (HRS)
2160.0


PMC BASELINE
2.0
0.0
AIR (KW)
0.0
2160.0
MET (HRS)


PMC BASELINE
2.0
0.0
CREW USAGE
0.0
2060.0
MET (HRS)

PMC BASELINE

MODEL	SSFF-INSTL	INSERTED FROM	144.00	HRS	TO	168.00	HRS
MODEL	PAYLOAD-ACT	INSERTED FROM	240.00	HRS	TO	240.18	HRS
MODEL	CORE-ACT	INSERTED FROM	336.00	HRS	TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED FROM	336.50	HRS	TO	336.95	HRS
MODEL	MSE-1	INSERTED FROM	336.95	HRS	TO	339.55	HRS
MODEL	MSE-2	INSERTED FROM	339.55	HRS	TO	342.15	HRS
MODEL	STANDBY	INSERTED FROM	342.15	HRS	TO	360.00	HRS
MODEL	BAKEOUT-1	INSERTED FROM	360.00	HRS	TO	365.00	HRS
MODEL	BAKEOUT-2	INSERTED FROM	364.00	HRS	TO	369.00	HRS
MODEL	PMZF-CdTe	INSERTED FROM	365.00	HRS	TO	459.90	HRS
MODEL	CGF-CdTe	INSERTED FROM	369.00	HRS	TO	463.90	HRS
MODEL	PMZF-GaAs	INSERTED FROM	459.90	HRS	TO	487.10	HRS
MODEL	CGF-GaAs	INSERTED FROM	463.90	HRS	TO	491.10	HRS
MODEL	PURGE-1	INSERTED FROM	487.10	HRS	TO	487.87	HRS
MODEL	PURGE-2	INSERTED FROM	491.10	HRS	TO	491.87	HRS
MODEL	PMZF-HgZnTe	INSERTED FROM	487.87	HRS	TO	640.57	HRS
MODEL	PMZF-HgZnTe	INSERTED FROM	640.58	HRS	TO	793.28	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	491.87	HRS	TO	644.58	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	644.59	HRS	TO	797.30	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	793.28	HRS	TO	809.78	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	797.30	HRS	TO	813.80	HRS
MODEL	MSE-1	INSERTED FROM	809.78	HRS	TO	812.38	HRS
MODEL	MSE-2	INSERTED FROM	813.80	HRS	TO	816.40	HRS
MODEL	BAKEOUT-1	INSERTED FROM	812.38	HRS	TO	817.38	HRS
MODEL	BAKEOUT-2	INSERTED FROM	816.40	HRS	TO	821.40	HRS
MODEL	PMZF-CdTe	INSERTED FROM	817.38	HRS	TO	912.28	HRS
MODEL	CGF-CdTe	INSERTED FROM	821.40	HRS	TO	916.30	HRS
MODEL	PMZF-GaAs	INSERTED FROM	912.28	HRS	TO	939.48	HRS
MODEL	CGF-GaAs	INSERTED FROM	916.30	HRS	TO	943.50	HRS
MODEL	PURGE-1	INSERTED FROM	939.48	HRS	TO	940.25	HRS
MODEL	PURGE-2	INSERTED FROM	943.50	HRS	TO	944.27	HRS
MODEL	PMZF-HgZnTe	INSERTED FROM	940.25	HRS	TO	1092.95	HRS
MODEL	PMZF-HgZnTe	INSERTED FROM	1092.96	HRS	TO	1245.66	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	944.27	HRS	TO	1096.98	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	1096.98	HRS	TO	1249.69	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1245.66	HRS	TO	1262.16	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1249.68	HRS	TO.	1266.18	HRS
MODEL	MSE-1	INSERTED FROM	1262.16	HRS	TO	1264.76	HRS
MODEL	MSE-2	INSERTED FROM	1266.18	HRS	TO	1268.78	HRS
MODEL	BAKEOUT-1	INSERTED FROM	1264.76	HRS	TO	1269.76	HRS
MODEL	BAKEOUT-2	INSERTED FROM	1268.78	HRS	TO	1273.78	HRS
MODEL	PMZF-CdTe	INSERTED FROM	1269.76	HRS	TO	1364.66	HRS
MODEL	CGF-CdTe	INSERTED FROM	1273.78	HRS	TO	1368.68	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1364.66	HRS	TO	1391.86	HRS
MODEL	CGF-GaAs	INSERTED FROM	1368.68	HRS	TO	1395.88	HRS
MODEL	PURGE-1	INSERTED FROM	1391.86	HRS	TO	1392.63	HRS
MODEL	PURGE-2	INSERTED FROM	1395.88	HRS	TO	1396.65	HRS
MODEL	PMZF-HgZnTe	INSERTED FROM	1392.63	HRS	TO	1545.33	HRS
MODEL	PMZF-HgZnTe	INSERTED FROM	1545.34	HRS	TO	1698.04	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	1396.65	HRS	TO	1549.36	HRS
MODEL	CGF-HgZnTe	INSERTED FROM	1549.36	HRS	TO	1702.07	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1698.04	HRS	TO	1714.54	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1702.06	HRS	TO	1718.56	HRS
MODEL	MSE-1	INSERTED FROM	1714.54	HRS	TO	1717.14	HRS
MODEL	MSE-2	INSERTED FROM	1718.56	HRS	TO	1721.16	HRS
MODEL	BAKEOUT-1	INSERTED FROM	1717.14	HRS	TO	1722.14	HRS
MODEL	BAKEOUT-2	INSERTED FROM	1721.16	HRS	TO	1726.16	HRS

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MODEL PMZF-CdTe      INSERTED FROM  1722.14 HRS TO  1817.04 HRS
MODEL CGF-CdTe       INSERTED FROM  1726.16 HRS TO  1821.06 HRS
MODEL PMZF-GaAs      INSERTED FROM  1817.04 HRS TO  1844.24 HRS
MODEL CGF-GaAs       INSERTED FROM  1821.06 HRS TO  1848.26 HRS
MODEL PURGE-1        INSERTED FROM  1844.24 HRS TO  1845.01 HRS
MODEL PURGE-2        INSERTED FROM  1848.26 HRS TO  1849.03 HRS
MODEL PMZF-HgZnTe    INSERTED FROM  1845.01 HRS TO  1997.71 HRS
MODEL PMZF-HgCdTe    INSERTED FROM  1997.72 HRS TO  2014.22 HRS
MODEL CGF-HgZnTe     INSERTED FROM  1849.03 HRS TO  2001.74 HRS
MODEL CGF-HgCdTe     INSERTED FROM  2001.74 HRS TO  2018.24 HRS
MODEL PMZF-HgCdTe    INSERTED FROM  2014.22 HRS TO  2030.72 HRS
MODEL CGF-HgCdTe     INSERTED FROM  2018.24 HRS TO  2034.74 HRS
MODEL FURNACE-SD-1   INSERTED FROM  2030.72 HRS TO  2030.87 HRS
MODEL FURNACE-SD-2   INSERTED FROM  2034.74 HRS TO  2034.89 HRS
MODEL SSFF-SHUTDN    INSERTED FROM  2034.89 HRS TO  2035.12 HRS


**** MAXIMUM RES1-POWER     5.853 KW
**** MAXIMUM RES2-DATA GENERATION  132.000 KBPS


**** TOTAL ENERGY RES1=    5738.28 KWH
**** TOTAL ENERGY RES2= 107270.85 KBPSH = 48271882.5 KBytes DATA VOLUME
GROUP  1 ENERGY RES1 =    5739.75 RES2 = 107270.84 CREW TIME (M-Hr) =    40.72
GROUP  2 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  3 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00


MAXIMUM NUMBER OF CREW =     1.000

AVG POWER SSFF = 3.3772

EXPERIMENTS          NO.RUNS  DESIRED RUNS  PERCENTAGE
SSFF-INSTL              1            1      100.00000000%
PAYLOAD-ACT             1            1      100.00000000%
CORE-ACT                1            1      100.00000000%
FURNACE-ACT             1            1      100.00000000%
MSE-1                   4            4      100.00000000%
MSE-2                   4            4      100.00000000%
STANDBY                 1            1      100.00000000%
BAKEOUT-1               4            4      100.00000000%
BAKEOUT-2               4            4      100.00000000%
```

F-CdTe	4	4	100.00000000%
-CdTe	4	4	100.00000000%
F-GaAs	4	4	100.00000000%
-GaAs	4	4	100.00000000%
GE-1	4	4	100.00000000%
GE-2	4	4	100.00000000%
F-HgZnTe	7	7	100.00000000%
-HgZnTe	7	7	100.00000000%
F-HgCdTe	5	5	100.00000000%
-HgCdTe	5	5	100.00000000%
NACE-SD-1	1	1	100.00000000%
NACE-SD-2	1	1	100.00000000%
F-SHUTDN	1	1	100.00000000%

PMC EXTENDED BASELINE SCENARIO DESCRIPTION

Scenario #9 demonstrates the adaptability of SSFF to handle samples requiring extended processing times while minimizing crew time. The time for processing the sample of HgZnTe is extended in both furnaces. This allows processing of one carousel of samples to be completed within the 90 day mission. As a results of the extended processing times no additional carousel exchange is needed and crew interaction with SSFF is therefore minimized.

PMC EXTENDED BASELINE SCENARIO OVERVIEW

The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

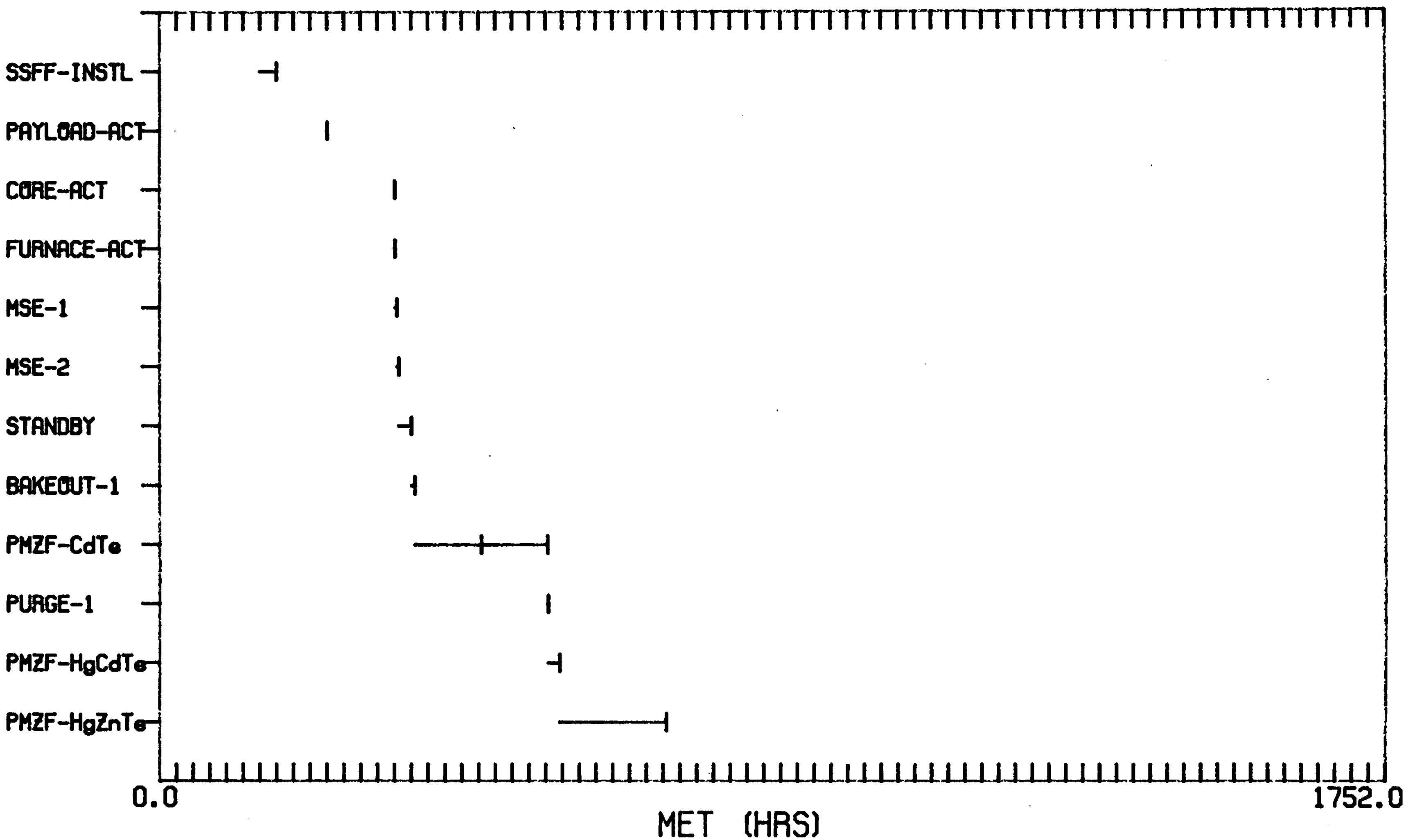
Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Until the time when resources are allocated for processing, the SSFF will remain in a standby mode. When resources are secured, samples may be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of the system and correct any problems.

A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of

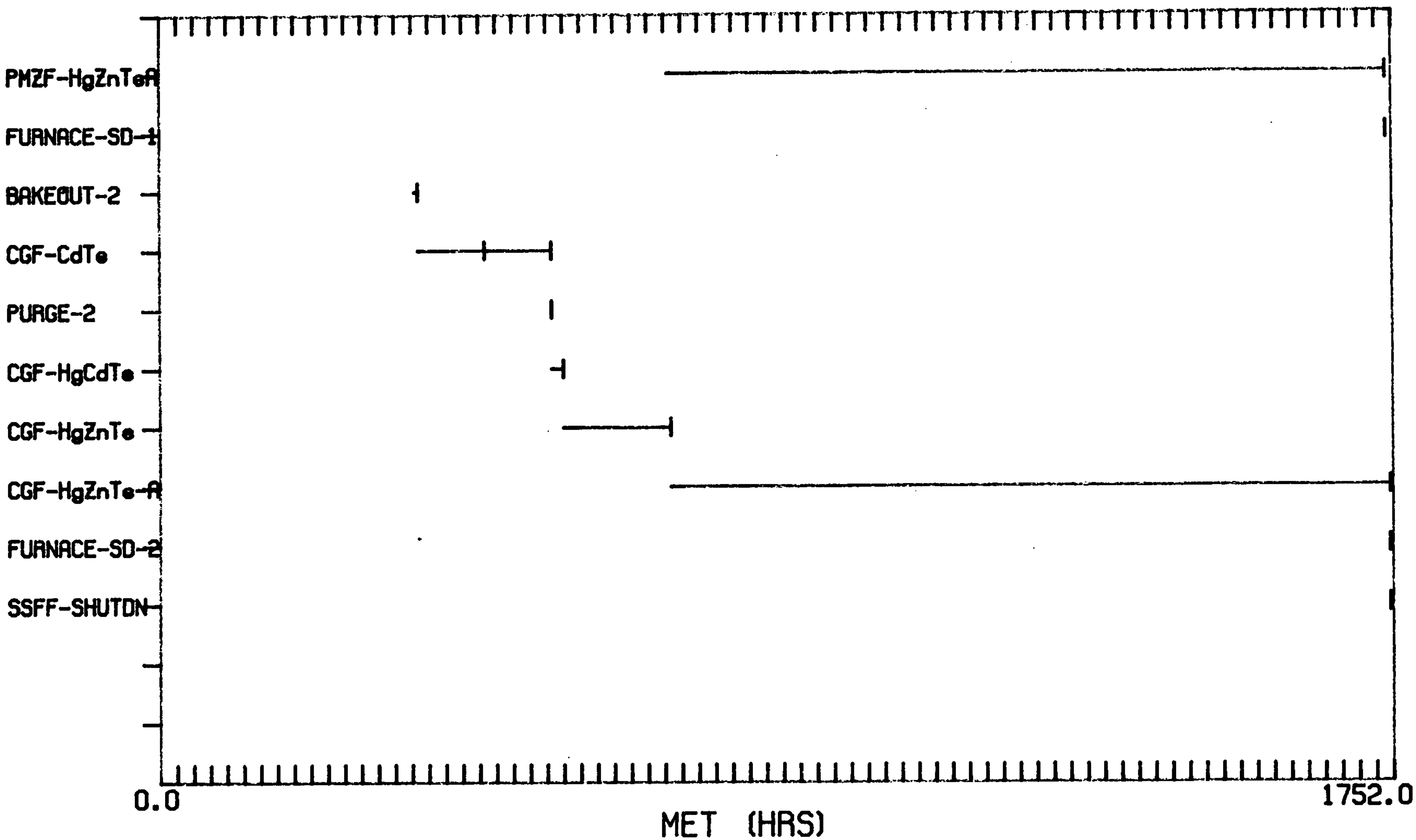
two samples of CdTe occur next. Upon completion of processing a single sample the carousel within the furnace module will deliver a subsequent sample to be processed. Purging of both furnace modules occurs after the first three samples in the scenario described. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). A sample of HgCdTe, HgZnTe and an extended sample of HgZnTe are processed within the furnace modules. Upon completion of the entire carousel of samples the Furnace Modules are returned to a standby mode.

From the standby mode complete shutdown can occur, however with crew available samples may be exchanged. The samples used in this scenario do not allow enough time for another carousel to be processed. Both furnaces will process one carousel apiece within a 90 day mission. Shutdown begins for the each furnace module after the completed carousel. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration requires the SSFF to vent processing gas from the furnace module, configure the TCS into the core rack, and place the furnace into the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

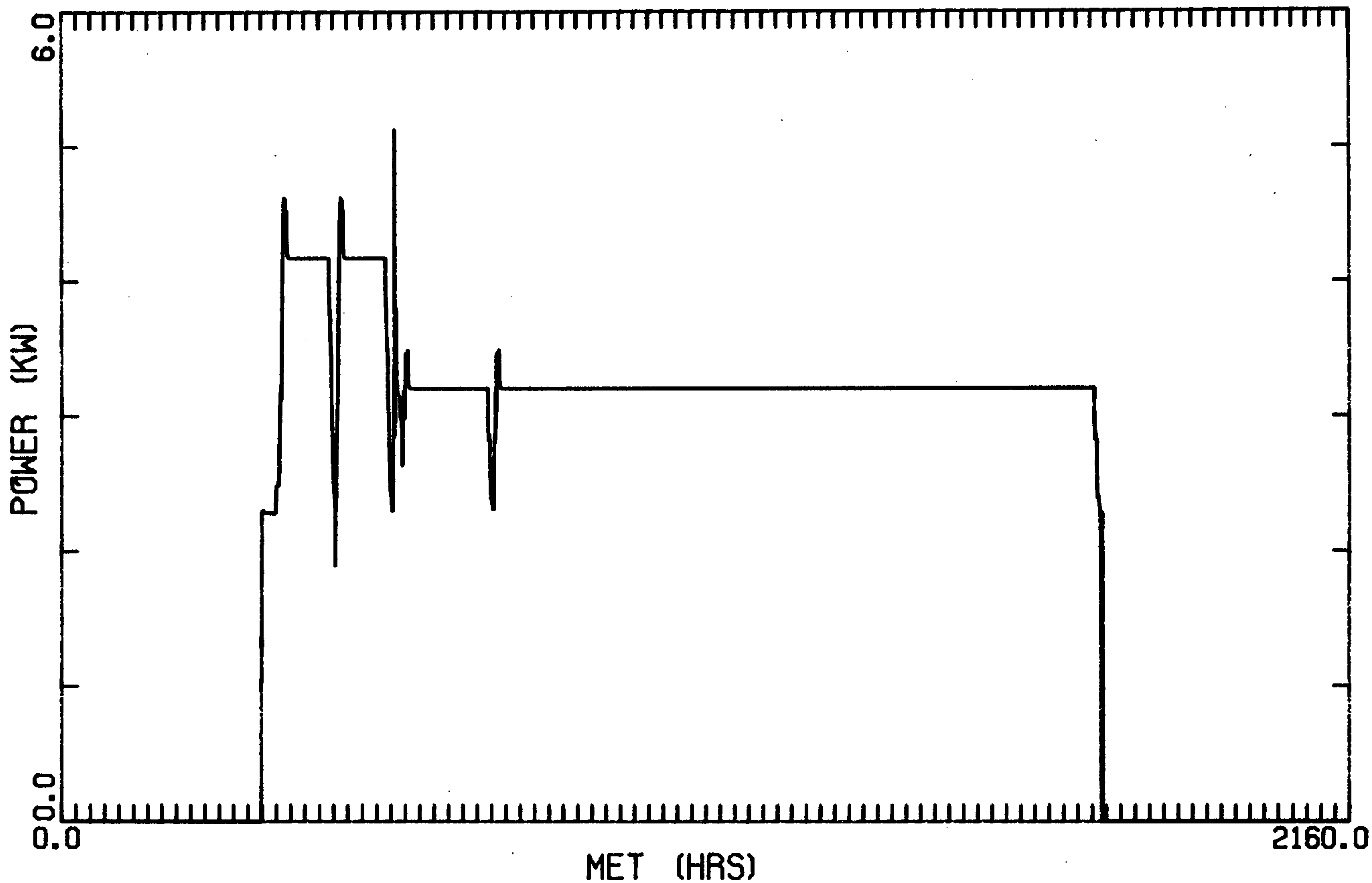
PMC EXTENDED



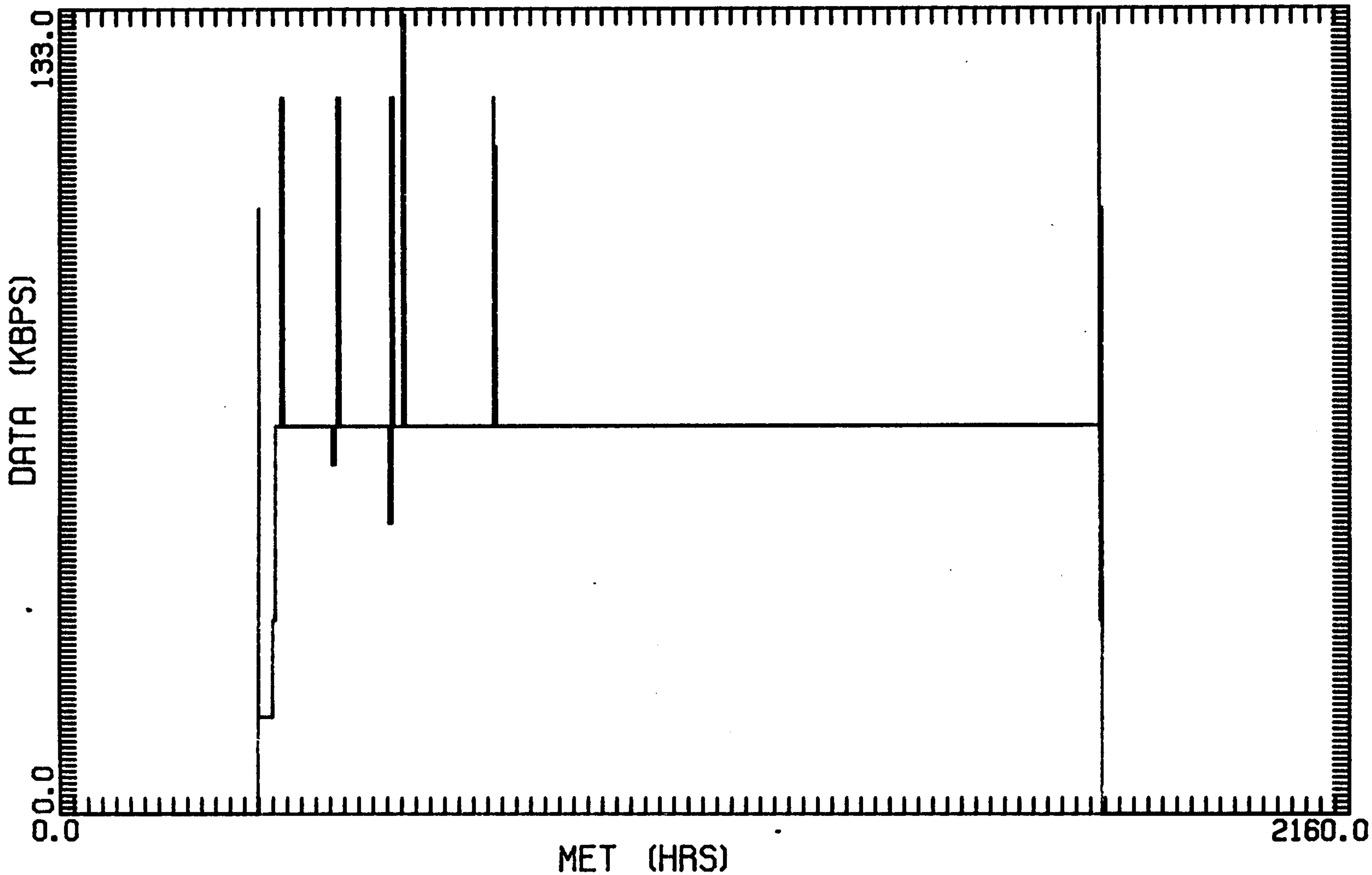
PMC EXTENDED

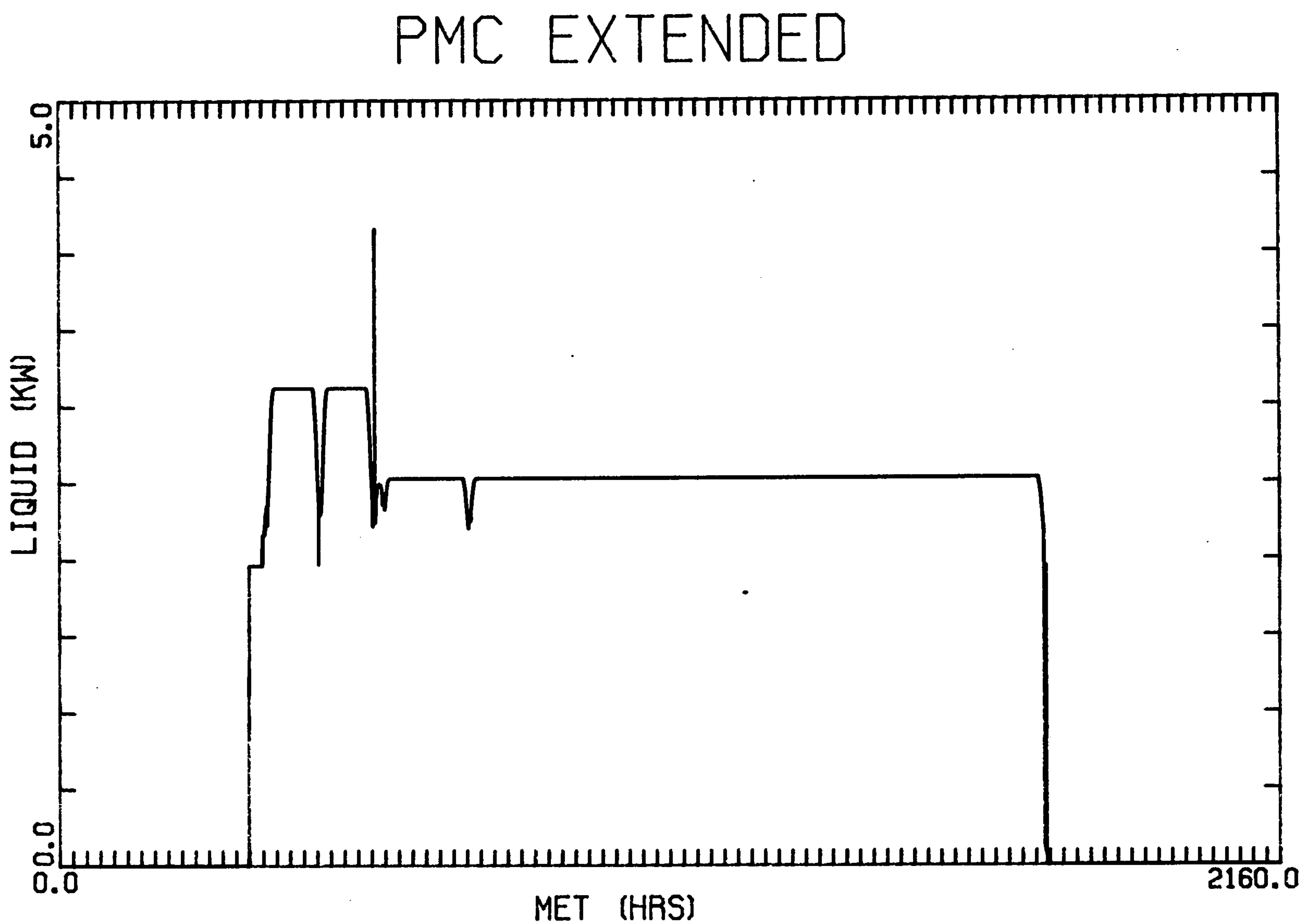


PMC EXTENDED

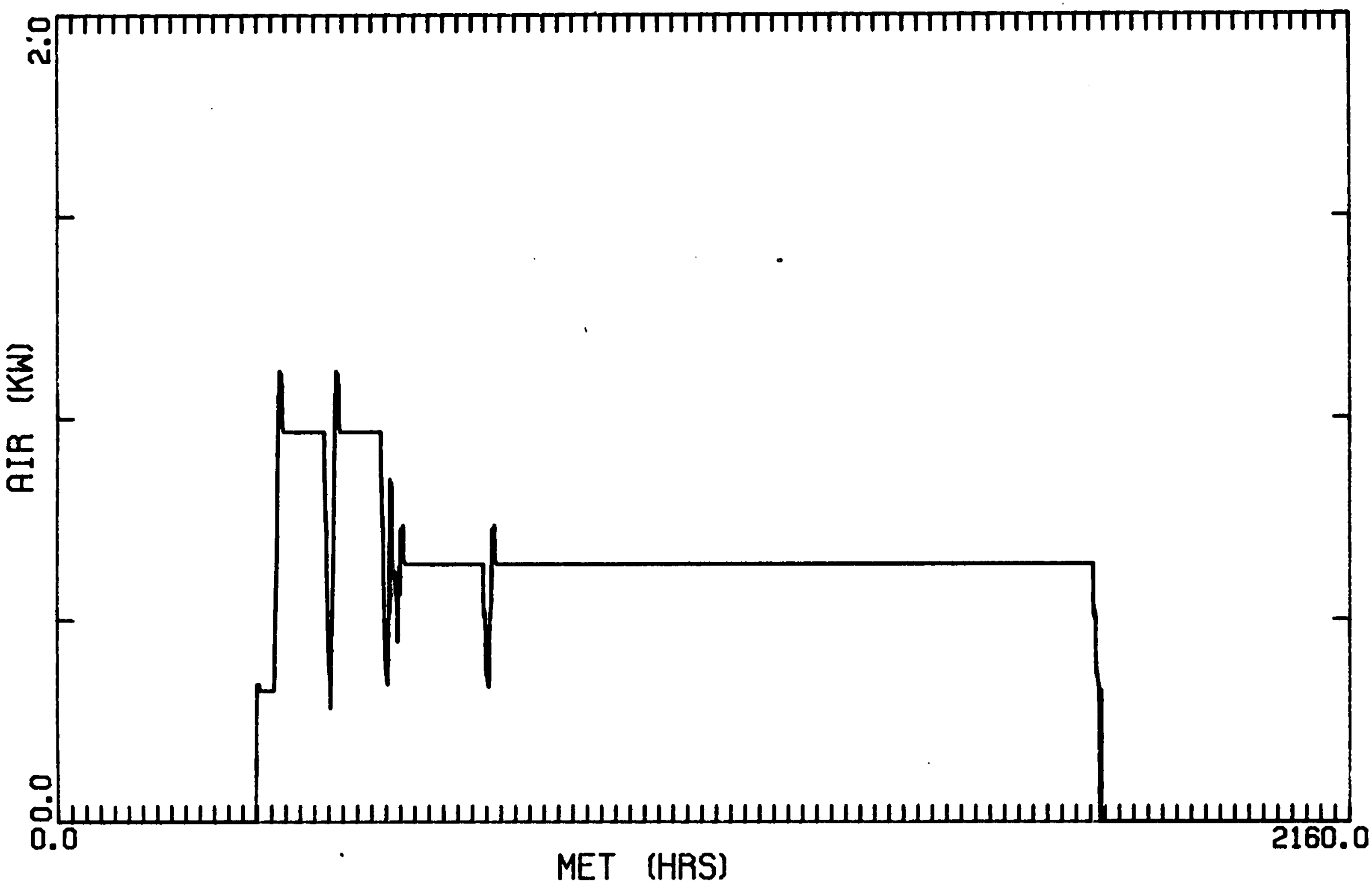


PMC EXTENDED

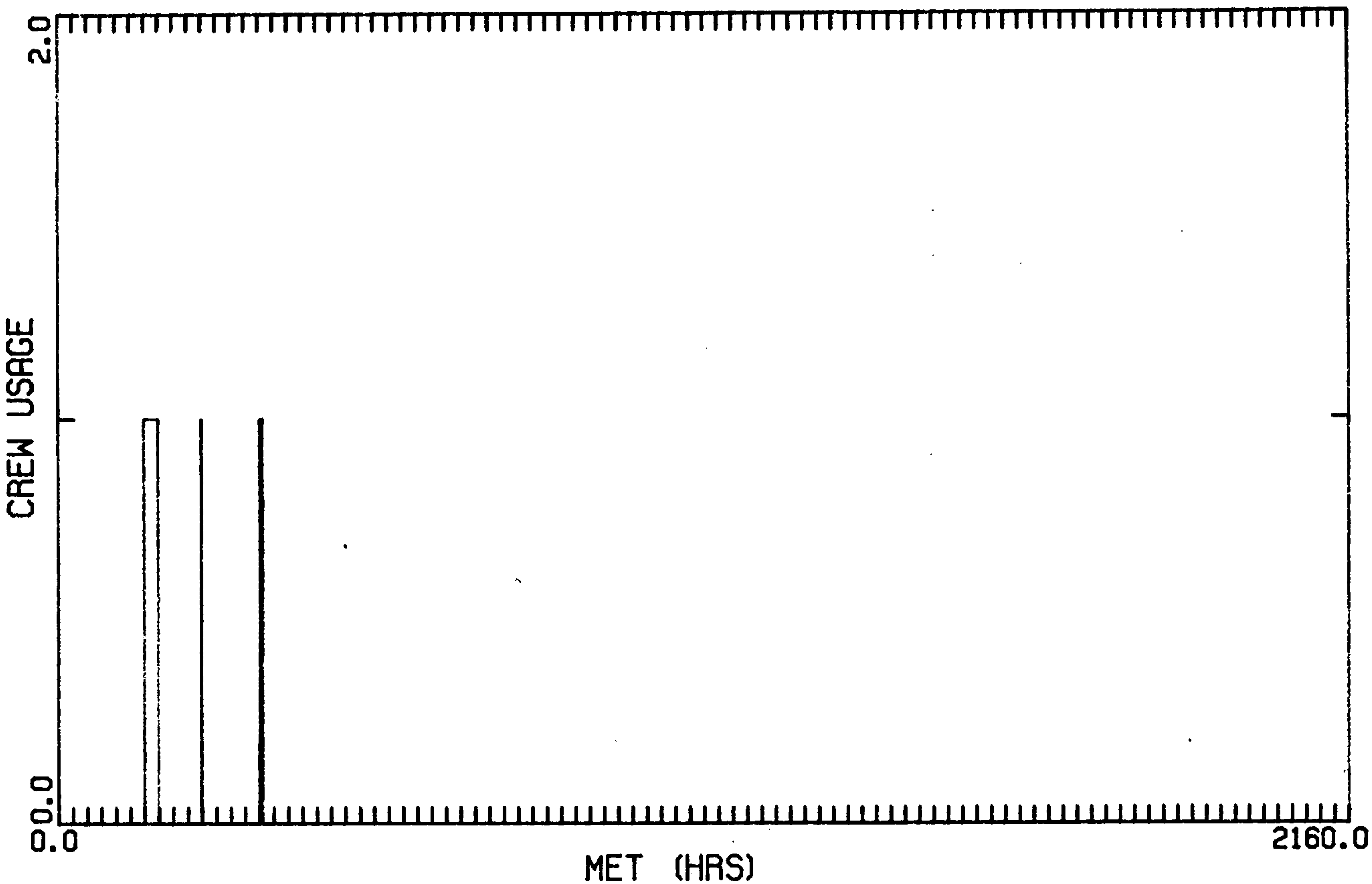



PMC EXTENDED
5.0
LIQUID (KW)
0.0
0.0
MET (HRS)
2160.0

PMC EXTENDED



PMC EXTENDED



PMC EXTENDED

```
MODEL SSFF-INSTL     INSERTED FROM   144.00 HRS TO   168.00 HRS
MODEL PAYLOAD-ACT    INSERTED FROM   240.00 HRS TO   240.18 HRS
MODEL CORE-ACT       INSERTED FROM   336.00 HRS TO   336.50 HRS
MODEL FURNACE-ACT    INSERTED FROM   336.50 HRS TO   336.95 HRS
MODEL MSE-1          INSERTED FROM   336.95 HRS TO   339.55 HRS
MODEL MSE-2          INSERTED FROM   339.55 HRS TO   342.15 HRS
MODEL STANDBY        INSERTED FROM   342.15 HRS TO   360.00 HRS
MODEL BAKEOUT-1      INSERTED FROM   360.00 HRS TO   365.00 HRS
MODEL PMZF-CdTe      INSERTED FROM   365.00 HRS TO   459.90 HRS
MODEL PMZF-CdTe      INSERTED FROM   459.92 HRS TO   554.82 HRS
MODEL PURGE-1        INSERTED FROM   554.82 HRS TO   555.58 HRS
MODEL PMZF-HgCdTe    INSERTED FROM   555.58 HRS TO   572.08 HRS
MODEL PMZF-HgZnTe    INSERTED FROM   572.08 HRS TO   724.78 HRS
MODEL PMZF-HgZnTeA   INSERTED FROM   724.78 HRS TO  1743.37 HRS
MODEL FURNACE-SD-1   INSERTED FROM  1743.37 HRS TO  1743.52 HRS
MODEL BAKEOUT-2      INSERTED FROM   364.00 HRS TO   369.00 HRS
MODEL CGF-CdTe       INSERTED FROM   369.00 HRS TO   463.90 HRS
MODEL CGF-CdTe       INSERTED FROM   463.92 HRS TO   558.82 HRS
MODEL PURGE-2        INSERTED FROM   558.82 HRS TO   559.58 HRS
MODEL CGF-HgCdTe     INSERTED FROM   559.58 HRS TO   576.08 HRS
MODEL CGF-HgZnTe     INSERTED FROM   576.08 HRS TO   728.79 HRS
MODEL CGF-HgZnTe-A   INSERTED FROM   728.79 HRS TO  1747.39 HRS
MODEL FURNACE-SD-2   INSERTED FROM  1747.39 HRS TO  1747.54 HRS
MODEL SSFF-SHUTDN    INSERTED FROM  1747.54 HRS TO  1747.77 HRS


**** MAXIMUM RES1-POWER    5.129 KW
**** MAXIMUM RES2-DATA GENERATION  132.000 KBPS


**** TOTAL ENERGY RES1=    4619.70 KWH
**** TOTAL ENERGY RES2=   89000.16 KBPSH = 40050072 KBytes DATA VOLUME
GROUP  1 ENERGY RES1 =    4622.88 RES2 =  89000.17 CREW TIME (M-Hr) =    28.32
GROUP  2 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  3 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =      0.00 CREW TIME (M-Hr) =     0.00


MAXIMUM NUMBER OF CREW =    1.000
```

AVG POWER SSFF = 3.2722

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
SSFF-INSTL	1	1	100.00000000%
PAYLOAD-ACT	1	1	100.00000000%
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE-1	1	1	100.00000000%
MSE-2	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT-1	1	1	100.00000000%
PMZF-CdTe	2	2	100.00000000%
PURGE-1	1	1	100.00000000%
PMZF-HgCdTe	1	1	100.00000000%
PMZF-HgZnTe	1	1	100.00000000%
PMZF-HgZnTeA	1	1	100.00000000%
FURNACE-SD-1	1	1	100.00000000%
BAKEOUT-2	1	1	100.00000000%
CGF-CdTe	2	2	100.00000000%
PURGE-2	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
FURNACE-SD-2	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

PMC EXTENDED

```
**** MAXIMUM RES1-LIQUID     4.167 KW
**** MAXIMUM RES2-AIR        1.118 KW


**** TOTAL ENERGY RES1=    3632.16 KWH
**** TOTAL ENERGY RES2=     932.62 KWH
GROUP  1 ENERGY RES1 =    3631.14 RES2 =     932.56 CREW TIME (M-Hr) =       0.00
GROUP  2 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  3 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =       0.00
```

PMC ALL SHORT SAMPLES SCENARIO DESCRIPTION

Scenario # 10 illustrates the maximum use of crew time. Furnace Module #1 and Furnace Module #2 process the same samples used in Scenario #4. These samples are GaAs and HgCdTe and require extremely short processing time. Upon completion of a carousel, the crew will exchange samples. The short processing cycles demand extensive crew time for changing samples. This scenario will demonstrate a total of 192 samples being processed over a 90 day mission.

PMC ALL SHORT SAMPLES SCENARIO OVERVIEW

The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

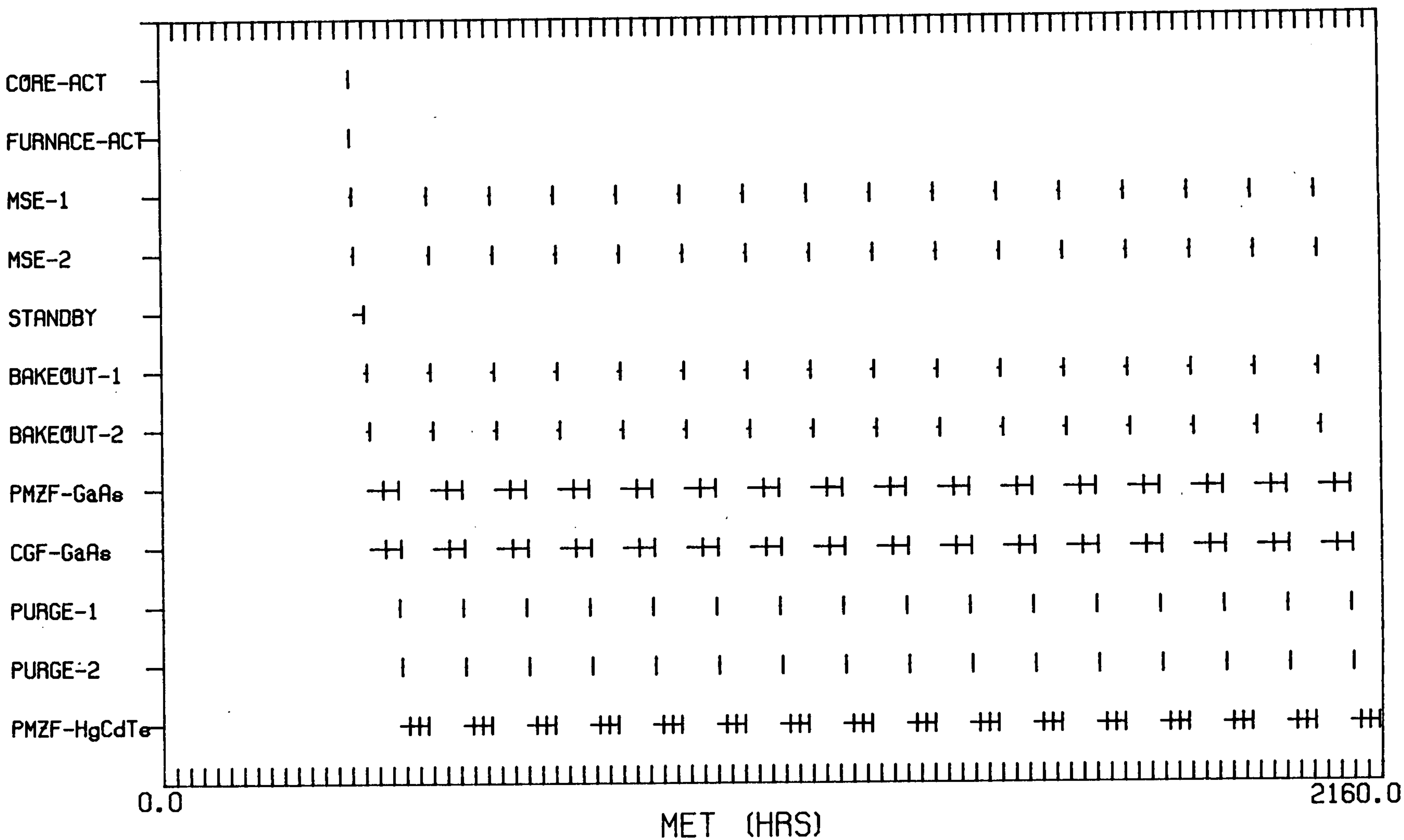
Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Samples can be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of systems and correction of any problems.

A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples occurs next. The samples include HgCdTe and GaAs. These samples require

extremely short processing times, therefore the crew time needed to exchange carousels will be increased. Upon completion of processing a single sample the carousel within the furnace module will deliver a subsequent sample to be processed. Purging of both furnace modules will occur after the first three samples in the scenario described. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). Three more similar sample are processed within the furnace modules. Upon completion of the entire carousel of samples the furnaces are returned to a standby mode.

From the standby mode complete shutdown can occur, however with crew available samples may be exchanged. From the standby mode, the manual sample exchange can be utilized and another set of samples loaded. The process continues as before processing carousels of samples in each furnace module. The cycle continues with an option to shutdown the a furnace module after every completed carousel. In this scenario a total of 16 carousels will be processed. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration requires venting of the furnace modules of processing gas, configure the TCS into the core rack, and place the furnaces into the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

PMC ALL SHØRT



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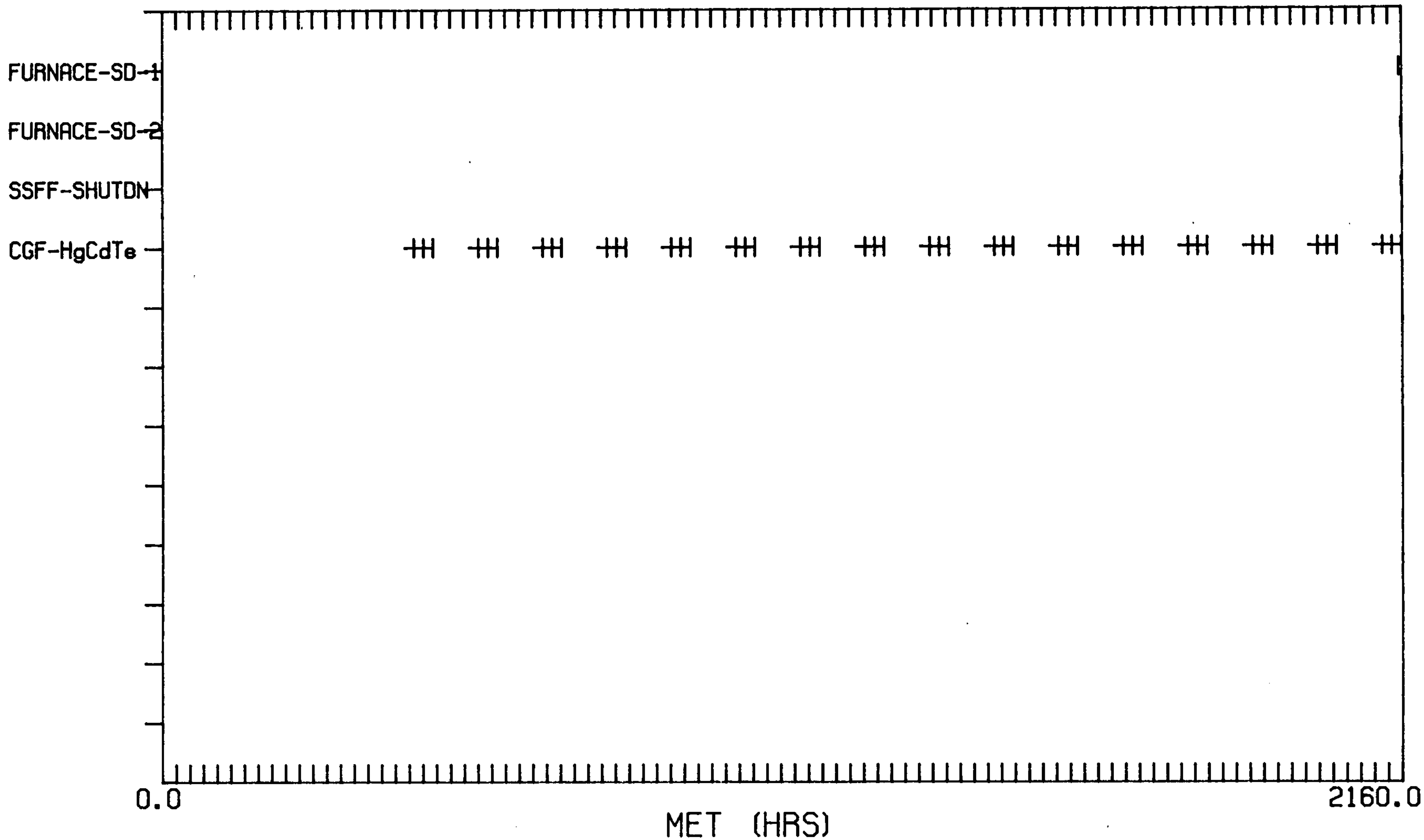

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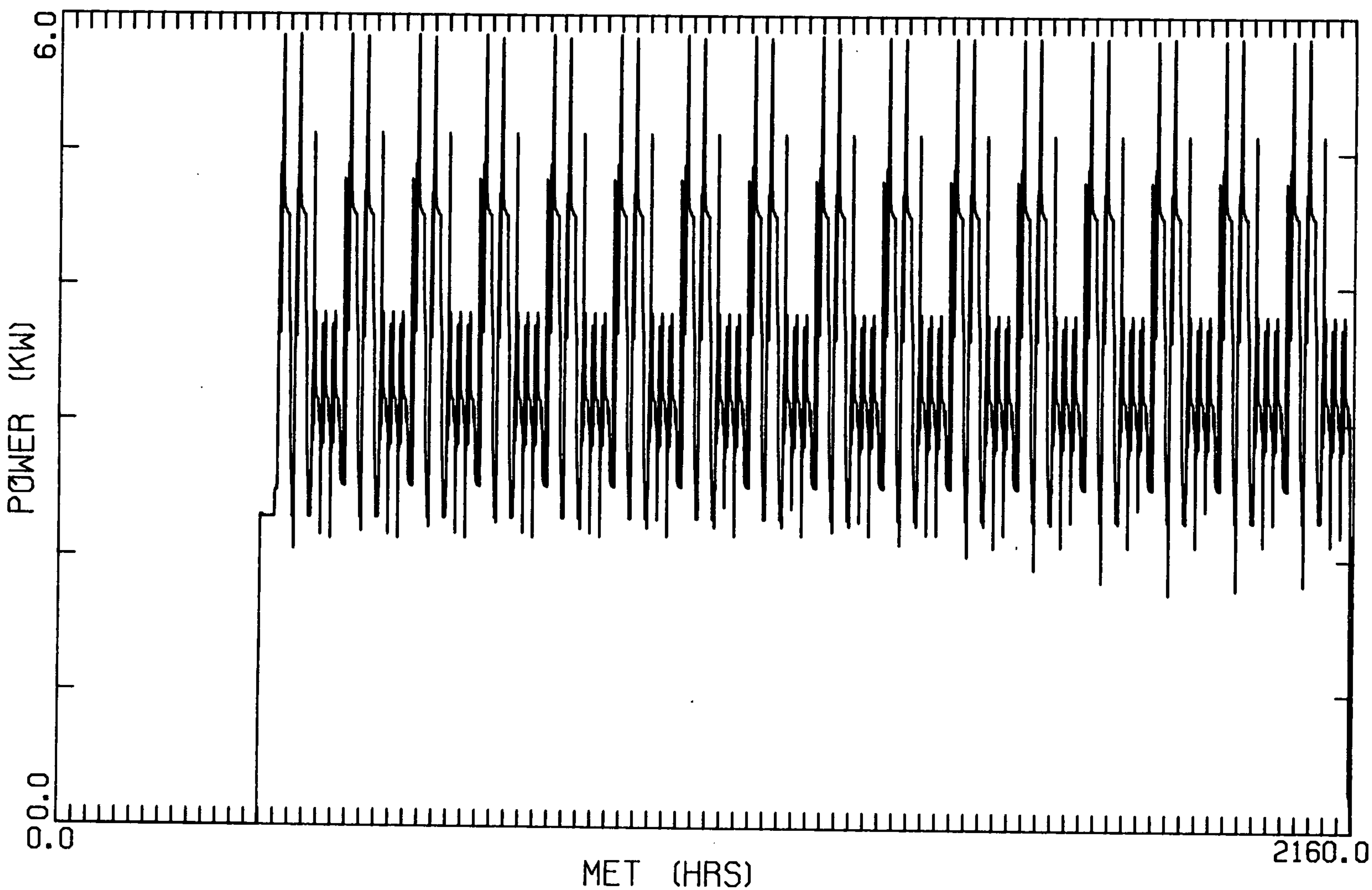

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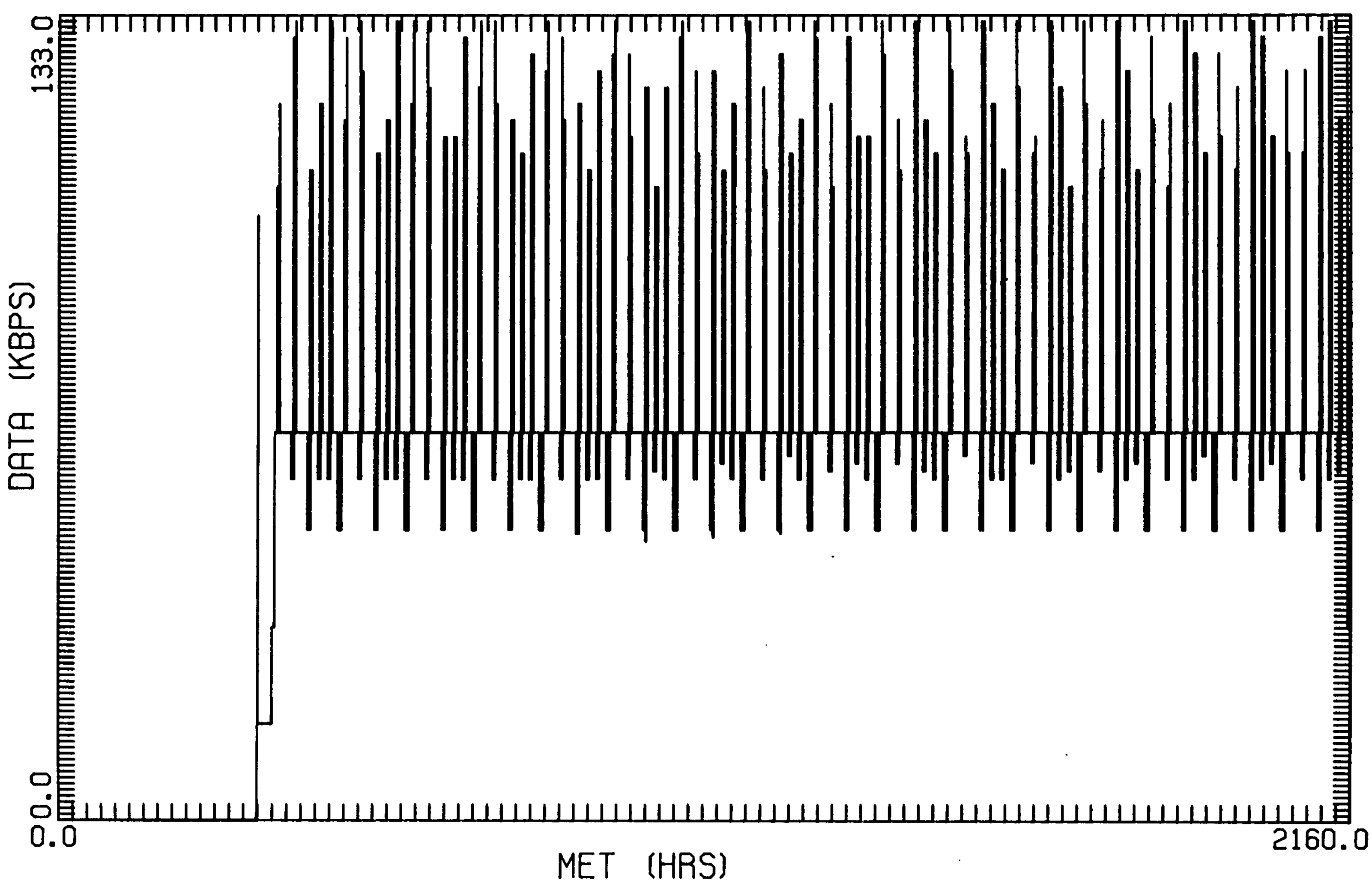

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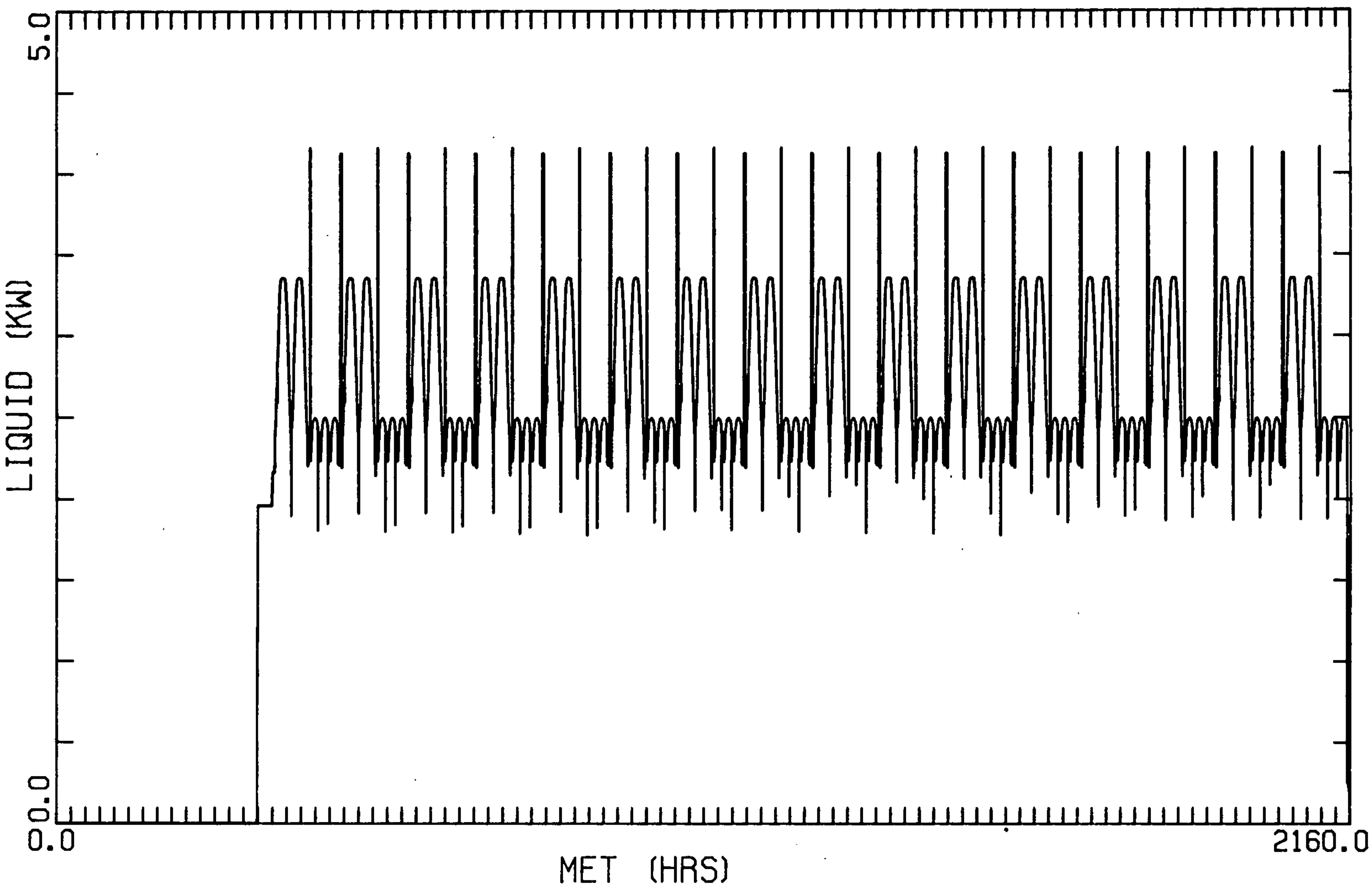
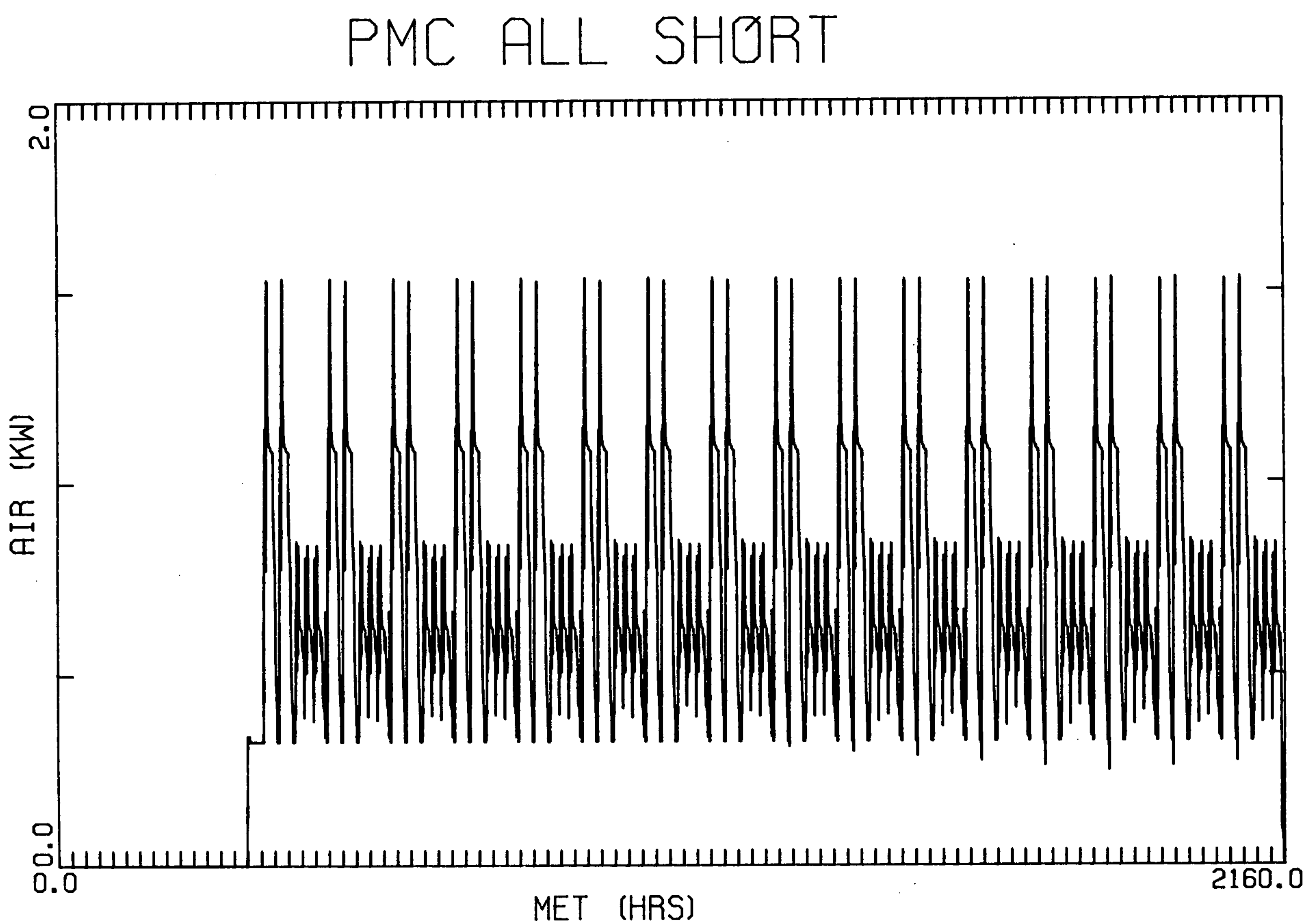
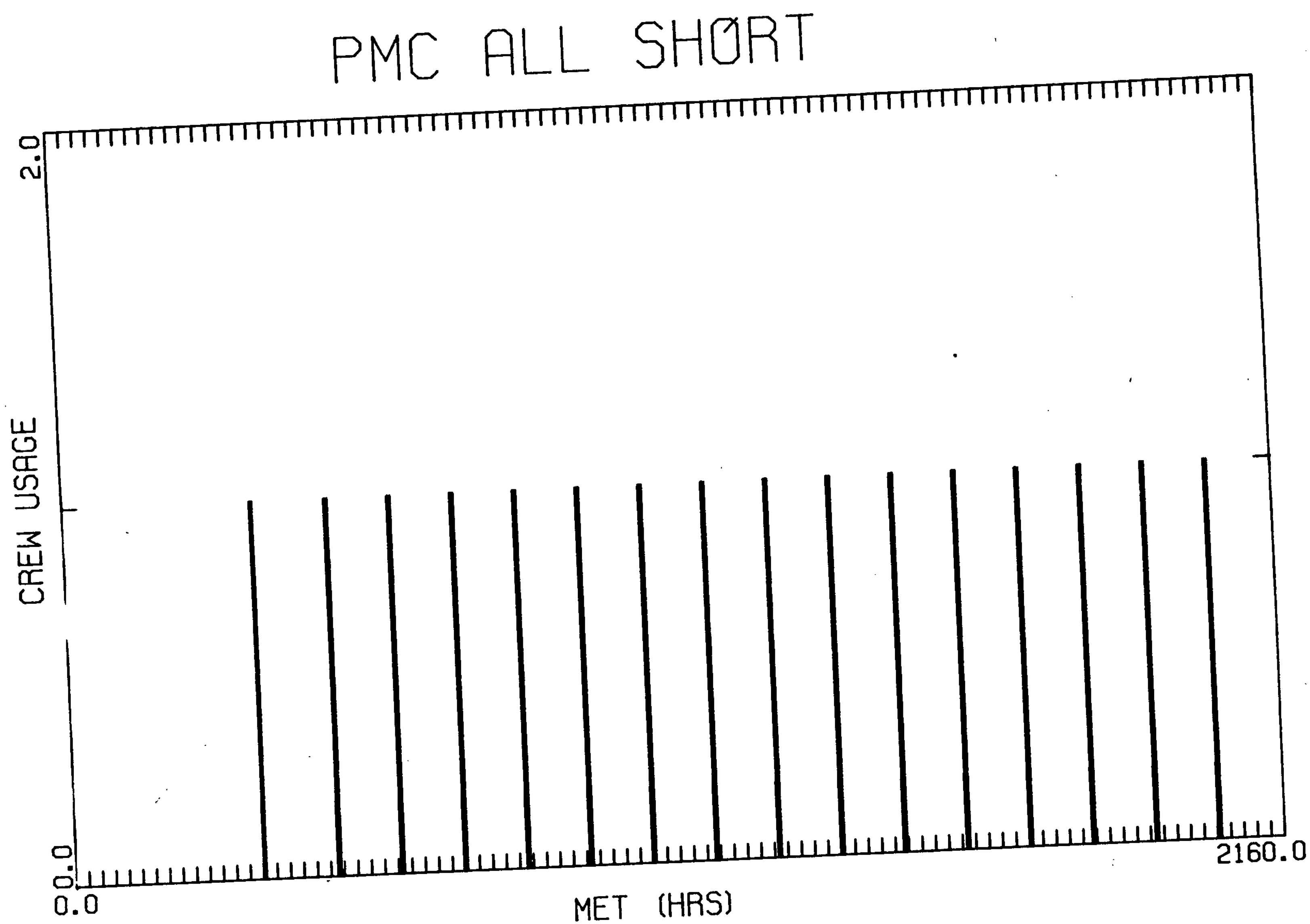



PMC ALL SHØRT
2.0
0.0
AIR (KW)
0.0
2160.0
MET (HRS)


PMC ALL SHØRT
CREW USAGE
2.0
0.0
0.0
2160.0
MET (HRS)

PMC ALL SHORT

MODEL	CORE-ACT	INSERTED	FROM	336.00 HRS	TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED	FROM	336.50 HRS	TO	336.95	HRS
MODEL	MSE-1	INSERTED	FROM	336.95 HRS	TO	339.55	HRS
MODEL	MSE-2	INSERTED	FROM	339.55 HRS	TO	342.15	HRS
MODEL	STANDBY	INSERTED	FROM	342.15 HRS	TO	360.00	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	360.00 HRS	TO	365.00	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	364.00 HRS	TO	369.00	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	365.00 HRS	TO	392.20	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	392.22 HRS	TO	419.42	HRS
MODEL	CGF-GaAs	INSERTED	FROM	369.00 HRS	TO	396.20	HRS
MODEL	CGF-GaAs	INSERTED	FROM	396.22 HRS	TO	423.42	HRS
MODEL	PURGE-1	INSERTED	FROM	419.42 HRS	TO	420.19	HRS
MODEL	PURGE-2	INSERTED	FROM	423.42 HRS	TO	424.19	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	420.18 HRS	TO	436.68	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	436.70 HRS	TO	453.20	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	453.22 HRS	TO	469.72	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	424.18 HRS	TO	440.68	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	440.70 HRS	TO	457.20	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	457.22 HRS	TO	473.72	HRS
MODEL	MSE-1	INSERTED	FROM	469.72 HRS	TO	472.32	HRS
MODEL	MSE-2	INSERTED	FROM	473.72 HRS	TO	476.32	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	472.32 HRS	TO	477.32	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	476.32 HRS	TO	481.32	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	477.32 HRS	TO	504.52	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	504.54 HRS	TO	531.74	HRS
MODEL	CGF-GaAs	INSERTED	FROM	481.32 HRS	TO	508.52	HRS
MODEL	CGF-GaAs	INSERTED	FROM	508.54 HRS	TO	535.74	HRS
MODEL	PURGE-1	INSERTED	FROM	531.74 HRS	TO	532.51	HRS
MODEL	PURGE-2	INSERTED	FROM	535.74 HRS	TO	536.51	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	532.51 HRS	TO	549.01	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	549.03 HRS	TO	565.53	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	565.55 HRS	TO	582.05	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	536.51 HRS	TO	553.01	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	553.03 HRS	TO	569.53	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	569.55 HRS	TO	586.05	HRS
MODEL	MSE-1	INSERTED	FROM	582.05 HRS	TO	584.65	HRS
MODEL	MSE-2	INSERTED	FROM	586.05 HRS	TO	588.65	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	584.65 HRS	TO	589.65	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	588.65 HRS	TO	593.65	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	589.65 HRS	TO	616.85	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	616.87 HRS	TO	644.07	HRS
MODEL	CGF-GaAs	INSERTED	FROM	593.65 HRS	TO	620.85	HRS
MODEL	CGF-GaAs	INSERTED	FROM	620.87 HRS	TO	648.07	HRS
MODEL	PURGE-1	INSERTED	FROM	644.07 HRS	TO	644.84	HRS
MODEL	PURGE-2	INSERTED	FROM	648.07 HRS	TO	648.84	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	644.84 HRS	TO	661.34	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	661.36 HRS	TO	677.86	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	677.88 HRS	TO	694.38	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	648.84 HRS	TO	665.34	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	665.36 HRS	TO	681.86	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	681.88 HRS	TO	698.38	HRS
MODEL	MSE-1	INSERTED	FROM	694.38 HRS	TO	696.98	HRS
MODEL	MSE-2	INSERTED	FROM	698.38 HRS	TO	700.98	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	696.98 HRS	TO	701.98	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	700.98 HRS	TO	705.98	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	701.98 HRS	TO	729.18	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	729.20 HRS	TO	756.40	HRS

MODEL CGF-GaAs	INSERTED FROM	705.98	HRS	TO	733.18	HRS
MODEL CGF-GaAs	INSERTED FROM	733.20	HRS	TO	760.40	HRS
MODEL PURGE-1	INSERTED FROM	756.40	HRS	TO	757.17	HRS
MODEL PURGE-2	INSERTED FROM	760.40	HRS	TO	761.17	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	757.17	HRS	TO	773.67	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	773.69	HRS	TO	790.19	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	790.21	HRS	TO	806.71	HRS
MODEL CGF-HgCdTe	INSERTED FROM	761.17	HRS	TO	777.67	HRS
MODEL CGF-HgCdTe	INSERTED FROM	777.69	HRS	TO	794.19	HRS
MODEL CGF-HgCdTe	INSERTED FROM	794.21	HRS	TO	810.71	HRS
MODEL MSE-1	INSERTED FROM	806.71	HRS	TO	809.31	HRS
MODEL MSE-2	INSERTED FROM	810.71	HRS	TO	813.31	HRS
MODEL BAKEOUT-1	INSERTED FROM	809.31	HRS	TO	814.31	HRS
MODEL BAKEOUT-2	INSERTED FROM	813.31	HRS	TO	818.31	HRS
MODEL PMZF-GaAs	INSERTED FROM	814.31	HRS	TO	841.51	HRS
MODEL PMZF-GaAs	INSERTED FROM	841.53	HRS	TO	868.73	HRS
MODEL CGF-GaAs	INSERTED FROM	818.31	HRS	TO	845.51	HRS
MODEL CGF-GaAs	INSERTED FROM	845.53	HRS	TO	872.73	HRS
MODEL PURGE-1	INSERTED FROM	868.73	HRS	TO	869.50	HRS
MODEL PURGE-2	INSERTED FROM	872.73	HRS	TO	873.50	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	869.50	HRS	TO	886.00	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	886.02	HRS	TO	902.52	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	902.54	HRS	TO	919.04	HRS
MODEL CGF-HgCdTe	INSERTED FROM	873.50	HRS	TO	890.00	HRS
MODEL CGF-HgCdTe	INSERTED FROM	890.02	HRS	TO	906.52	HRS
MODEL CGF-HgCdTe	INSERTED FROM	906.54	HRS	TO	923.04	HRS
MODEL MSE-1	INSERTED FROM	919.04	HRS	TO	921.64	HRS
MODEL MSE-2	INSERTED FROM	923.04	HRS	TO	925.64	HRS
MODEL BAKEOUT-1	INSERTED FROM	921.64	HRS	TO	926.64	HRS
MODEL BAKEOUT-2	INSERTED FROM	925.64	HRS	TO	930.64	HRS
MODEL PMZF-GaAs	INSERTED FROM	926.64	HRS	TO	953.84	HRS
MODEL PMZF-GaAs	INSERTED FROM	953.86	HRS	TO	981.06	HRS
MODEL CGF-GaAs	INSERTED FROM	930.64	HRS	TO	957.84	HRS
MODEL CGF-GaAs	INSERTED FROM	957.86	HRS	TO	985.06	HRS
MODEL PURGE-1	INSERTED FROM	981.06	HRS	TO	981.83	HRS
MODEL PURGE-2	INSERTED FROM	985.05	HRS	TO	985.82	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	981.83	HRS	TO	998.33	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	998.35	HRS	TO	1014.85	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	1014.87	HRS	TO	1031.37	HRS
MODEL CGF-HgCdTe	INSERTED FROM	985.83	HRS	TO	1002.33	HRS
MODEL CGF-HgCdTe	INSERTED FROM	1002.35	HRS	TO	1018.85	HRS
MODEL CGF-HgCdTe	INSERTED FROM	1018.87	HRS	TO	1035.37	HRS
MODEL MSE-1	INSERTED FROM	1031.37	HRS	TO	1033.97	HRS
MODEL MSE-2	INSERTED FROM	1035.37	HRS	TO	1037.97	HRS
MODEL BAKEOUT-1	INSERTED FROM	1033.97	HRS	TO	1038.97	HRS
MODEL BAKEOUT-2	INSERTED FROM	1037.97	HRS	TO	1042.97	HRS
MODEL PMZF-GaAs	INSERTED FROM	1038.97	HRS	TO	1066.17	HRS
MODEL PMZF-GaAs	INSERTED FROM	1066.19	HRS	TO	1093.39	HRS
MODEL CGF-GaAs	INSERTED FROM	1042.97	HRS	TO	1070.17	HRS
MODEL CGF-GaAs	INSERTED FROM	1070.19	HRS	TO	1097.39	HRS
MODEL PURGE-1	INSERTED FROM	1093.39	HRS	TO	1094.16	HRS
MODEL PURGE-2	INSERTED FROM	1097.38	HRS	TO	1098.15	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	1094.16	HRS	TO	1110.66	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	1110.68	HRS	TO	1127.18	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	1127.20	HRS	TO	1143.70	HRS
MODEL CGF-HgCdTe	INSERTED FROM	1098.16	HRS	TO	1114.66	HRS
MODEL CGF-HgCdTe	INSERTED FROM	1114.68	HRS	TO	1131.18	HRS
MODEL CGF-HgCdTe	INSERTED FROM	1131.20	HRS	TO	1147.70	HRS
MODEL MSE-1	INSERTED FROM	1143.70	HRS	TO	1146.30	HRS
MODEL MSE-2	INSERTED FROM	1147.70	HRS	TO	1150.30	HRS

MODEL	BAKEOUT-1	INSERTED FROM	1146.30	HRS	TO	1151.30	HRS
MODEL	BAKEOUT-2	INSERTED FROM	1150.30	HRS	TO	1155.30	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1151.30	HRS	TO	1178.50	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1178.52	HRS	TO	1205.72	HRS
MODEL	CGF-GaAs	INSERTED FROM	1155.30	HRS	TO	1182.50	HRS
MODEL	CGF-GaAs	INSERTED FROM	1182.52	HRS	TO	1209.72	HRS
MODEL	PURGE-1	INSERTED FROM	1205.72	HRS	TO	1206.49	HRS
MODEL	PURGE-2	INSERTED FROM	1209.71	HRS	TO	1210.48	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1206.49	HRS	TO	1222.99	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1223.01	HRS	TO	1239.51	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1239.53	HRS	TO	1256.03	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1210.49	HRS	TO	1226.99	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1227.01	HRS	TO	1243.51	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1243.53	HRS	TO	1260.03	HRS
MODEL	MSE-1	INSERTED FROM	1256.03	HRS	TO	1258.63	HRS
MODEL	MSE-2	INSERTED FROM	1260.03	HRS	TO	1262.63	HRS
MODEL	BAKEOUT-1	INSERTED FROM	1258.63	HRS	TO	1263.63	HRS
MODEL	BAKEOUT-2	INSERTED FROM	1262.63	HRS	TO	1267.63	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1263.63	HRS	TO	1290.83	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1290.85	HRS	TO	1318.05	HRS
MODEL	CGF-GaAs	INSERTED FROM	1267.63	HRS	TO	1294.83	HRS
MODEL	CGF-GaAs	INSERTED FROM	1294.85	HRS	TO	1322.05	HRS
MODEL	PURGE-1	INSERTED FROM	1318.05	HRS	TO	1318.82	HRS
MODEL	PURGE-2	INSERTED FROM	1322.04	HRS	TO	1322.81	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1318.82	HRS	TO	1335.32	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1335.34	HRS	TO	1351.84	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1351.86	HRS	TO	1368.36	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1322.82	HRS	TO	1339.32	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1339.34	HRS	TO	1355.84	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1355.86	HRS	TO	1372.36	HRS
MODEL	MSE-1	INSERTED FROM	1368.36	HRS	TO	1370.96	HRS
MODEL	MSE-2	INSERTED FROM	1372.36	HRS	TO	1374.96	HRS
MODEL	BAKEOUT-1	INSERTED FROM	1370.96	HRS	TO	1375.96	HRS
MODEL	BAKEOUT-2	INSERTED FROM	1374.96	HRS	TO	1379.96	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1375.96	HRS	TO	1403.16	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1403.18	HRS	TO	1430.38	HRS
MODEL	CGF-GaAs	INSERTED FROM	1379.96	HRS	TO	1407.16	HRS
MODEL	CGF-GaAs	INSERTED FROM	1407.18	HRS	TO	1434.38	HRS
MODEL	PURGE-1	INSERTED FROM	1430.38	HRS	TO	1431.15	HRS
MODEL	PURGE-2	INSERTED FROM	1434.37	HRS	TO	1435.14	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1431.15	HRS	TO	1447.65	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1447.67	HRS	TO	1464.17	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1464.19	HRS	TO	1480.69	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1435.15	HRS	TO	1451.65	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1451.67	HRS	TO	1468.17	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1468.19	HRS	TO	1484.69	HRS
MODEL	MSE-1	INSERTED FROM	1480.69	HRS	TO	1483.29	HRS
MODEL	MSE-2	INSERTED FROM	1484.69	HRS	TO	1487.29	HRS
MODEL	BAKEOUT-1	INSERTED FROM	1483.29	HRS	TO	1488.29	HRS
MODEL	BAKEOUT-2	INSERTED FROM	1487.29	HRS	TO	1492.29	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1488.29	HRS	TO	1515.49	HRS
MODEL	PMZF-GaAs	INSERTED FROM	1515.51	HRS	TO	1542.71	HRS
MODEL	CGF-GaAs	INSERTED FROM	1492.29	HRS	TO	1519.49	HRS
MODEL	CGF-GaAs	INSERTED FROM	1519.51	HRS	TO	1546.71	HRS
MODEL	PURGE-1	INSERTED FROM	1542.71	HRS	TO	1543.48	HRS
MODEL	PURGE-2	INSERTED FROM	1546.70	HRS	TO	1547.47	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1543.48	HRS	TO	1559.98	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1560.00	HRS	TO	1576.50	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	1576.52	HRS	TO	1593.02	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	1547.48	HRS	TO	1563.98	HRS

MODEL	CGF-HgCdTe	INSERTED	FROM	1564.00	HRS	TO	1580.50	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1580.52	HRS	TO	1597.02	HRS
MODEL	MSE-1	INSERTED	FROM	1593.02	HRS	TO	1595.62	HRS
MODEL	MSE-2	INSERTED	FROM	1597.02	HRS	TO	1599.62	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	1595.62	HRS	TO	1600.62	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	1599.62	HRS	TO	1604.62	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1600.62	HRS	TO	1627.82	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1627.84	HRS	TO	1655.04	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1604.62	HRS	TO	1631.82	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1631.84	HRS	TO	1659.04	HRS
MODEL	PURGE-1	INSERTED	FROM	1655.04	HRS	TO	1655.81	HRS
MODEL	PURGE-2	INSERTED	FROM	1659.03	HRS	TO	1659.80	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1655.81	HRS	TO	1672.31	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1672.33	HRS	TO	1688.83	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1688.85	HRS	TO	1705.35	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1659.81	HRS	TO	1676.31	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1676.33	HRS	TO	1692.83	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1692.85	HRS	TO	1709.35	HRS
MODEL	MSE-1	INSERTED	FROM	1705.35	HRS	TO	1707.95	HRS
MODEL	MSE-2	INSERTED	FROM	1709.35	HRS	TO	1711.95	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	1707.95	HRS	TO	1712.95	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	1711.95	HRS	TO	1716.95	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1712.95	HRS	TO	1740.15	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1740.17	HRS	TO	1767.37	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1716.95	HRS	TO	1744.15	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1744.17	HRS	TO	1771.37	HRS
MODEL	PURGE-1	INSERTED	FROM	1767.37	HRS	TO	1768.14	HRS
MODEL	PURGE-2	INSERTED	FROM	1771.36	HRS	TO	1772.13	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1768.14	HRS	TO	1784.64	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1784.66	HRS	TO	1801.16	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1801.18	HRS	TO	1817.68	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1772.14	HRS	TO	1788.64	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1788.66	HRS	TO	1805.16	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1805.18	HRS	TO	1821.68	HRS
MODEL	MSE-1	INSERTED	FROM	1817.68	HRS	TO	1820.28	HRS
MODEL	MSE-2	INSERTED	FROM	1821.68	HRS	TO	1824.28	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	1820.28	HRS	TO	1825.28	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	1824.28	HRS	TO	1829.28	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1825.28	HRS	TO	1852.48	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1852.50	HRS	TO	1879.70	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1829.28	HRS	TO	1856.48	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1856.50	HRS	TO	1883.70	HRS
MODEL	PURGE-1	INSERTED	FROM	1879.70	HRS	TO	1880.47	HRS
MODEL	PURGE-2	INSERTED	FROM	1883.69	HRS	TO	1884.46	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1880.47	HRS	TO	1896.97	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1896.99	HRS	TO	1913.49	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	1913.51	HRS	TO	1930.01	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1884.47	HRS	TO	1900.97	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1900.99	HRS	TO	1917.49	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1917.51	HRS	TO	1934.01	HRS
MODEL	MSE-1	INSERTED	FROM	1930.01	HRS	TO	1932.61	HRS
MODEL	MSE-2	INSERTED	FROM	1934.01	HRS	TO	1936.61	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	1932.61	HRS	TO	1937.61	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	1936.61	HRS	TO	1941.61	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1937.61	HRS	TO	1964.81	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	1964.83	HRS	TO	1992.03	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1941.61	HRS	TO	1968.81	HRS
MODEL	CGF-GaAs	INSERTED	FROM	1968.83	HRS	TO	1996.03	HRS
MODEL	PURGE-1	INSERTED	FROM	1992.03	HRS	TO	1992.80	HRS
MODEL	PURGE-2	INSERTED	FROM	1996.02	HRS	TO	1996.79	HRS

MODEL	PMZF-HgCdTe	INSERTED	FROM	1992.80	HRS	TO	2009.30	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	2009.32	HRS	TO	2025.82	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	2025.84	HRS	TO	2042.34	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	1996.80	HRS	TO	2013.30	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	2013.32	HRS	TO	2029.82	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	2029.84	HRS	TO	2046.34	HRS
MODEL	MSE-1	INSERTED	FROM	2042.34	HRS	TO	2044.94	HRS
MODEL	MSE-2	INSERTED	FROM	2046.34	HRS	TO	2048.94	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	2044.94	HRS	TO	2049.94	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	2048.94	HRS	TO	2053.94	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	2049.94	HRS	TO	2077.14	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	2077.16	HRS	TO	2104.36	HRS
MODEL	CGF-GaAs	INSERTED	FROM	2053.94	HRS	TO	2081.14	HRS
MODEL	CGF-GaAs	INSERTED	FROM	2081.16	HRS	TO	2108.36	HRS
MODEL	PURGE-1	INSERTED	FROM	2104.36	HRS	TO	2105.13	HRS
MODEL	PURGE-2	INSERTED	FROM	2108.35	HRS	TO	2109.12	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	2105.13	HRS	TO	2121.63	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	2121.65	HRS	TO	2138.15	HRS
MODEL	PMZF-HgCdTe	INSERTED	FROM	2138.17	HRS	TO	2154.67	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	2109.13	HRS	TO	2125.63	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	2125.65	HRS	TO	2142.15	HRS
MODEL	CGF-HgCdTe	INSERTED	FROM	2142.17	HRS	TO	2158.67	HRS
MODEL	FURNACE-SD-1	INSERTED	FROM	2154.67	HRS	TO	2154.82	HRS
MODEL	FURNACE-SD-2	INSERTED	FROM	2158.67	HRS	TO	2158.82	HRS
MODEL	SSFF-SHUTDN	INSERTED	FROM	2158.82	HRS	TO	2159.05	HRS

**** MAXIMUM RES1-POWER 5.853 KW
**** MAXIMUM RES2-DATA GENERATION 132.000 KBPS

**** TOTAL ENERGY RES1= 6408.14 KWH
**** TOTAL ENERGY RES2= 114663.84 KBPSH = 51598728 KBytes DATA VOLUME

GROUP	1	ENERGY RES1 =	6301.55	RES2 =	106641.80	CREW TIME (M-Hr) =	66.13
GROUP	2	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	3	ENERGY RES1 =	105.42	RES2 =	8022.00	CREW TIME (M-Hr) =	0.00
GROUP	4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP	20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 3.5151

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE-1	16	16	100.00000000%
MSE-2	16	16	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT-1	16	16	100.00000000%
BAKEOUT-2	16	16	100.00000000%
PMZF-GaAs	32	32	100.00000000%
CGF-GaAs	32	32	100.00000000%
PURGE-1	16	16	100.00000000%
PURGE-2	16	16	100.00000000%
PMZF-HgCdTe	48	48	100.00000000%
CGF-HgCdTe	48	48	100.00000000%
FURNACE-SD-1	1	1	100.00000000%
FURNACE-SD-2	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

PMC ALL SHORT

**** MAXIMUM RES1-LIQUID 4.224 KW
**** MAXIMUM RES2-AIR 1.536 KW

**** TOTAL ENERGY RES1= 4973.13 KWH
**** TOTAL ENERGY RES2= 1323.51 KWH

GROUP 1	ENERGY RES1 =	4915.75	RES2 =	1287.72	CREW TIME (M-Hr) =	0.00
GROUP 2	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 3	ENERGY RES1 =	57.48	RES2 =	35.82	CREW TIME (M-Hr) =	0.00
GROUP 4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00

PMC PEAK POWER SCENARIO DESCRIPTION

Scenario #11 portrays combinations of long and short processing times in both furnaces. The model purposely allowed peak power to be obtained in both Furnace Modules simultaneously. It was assumed that SSF mission timelines would try to avoid this scenario but that there was a possibility of it occurring. The data generated by this scenario depicts peak power requirements occurring with two furnace operation for these type of samples. Furnace Module #1 and Furnace Module #2 will process two samples of CdTe, GaAs, HgZnTe, and an extended sample of HgZnTe.

PMC PEAK POWER SCENARIO OVERVIEW

The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

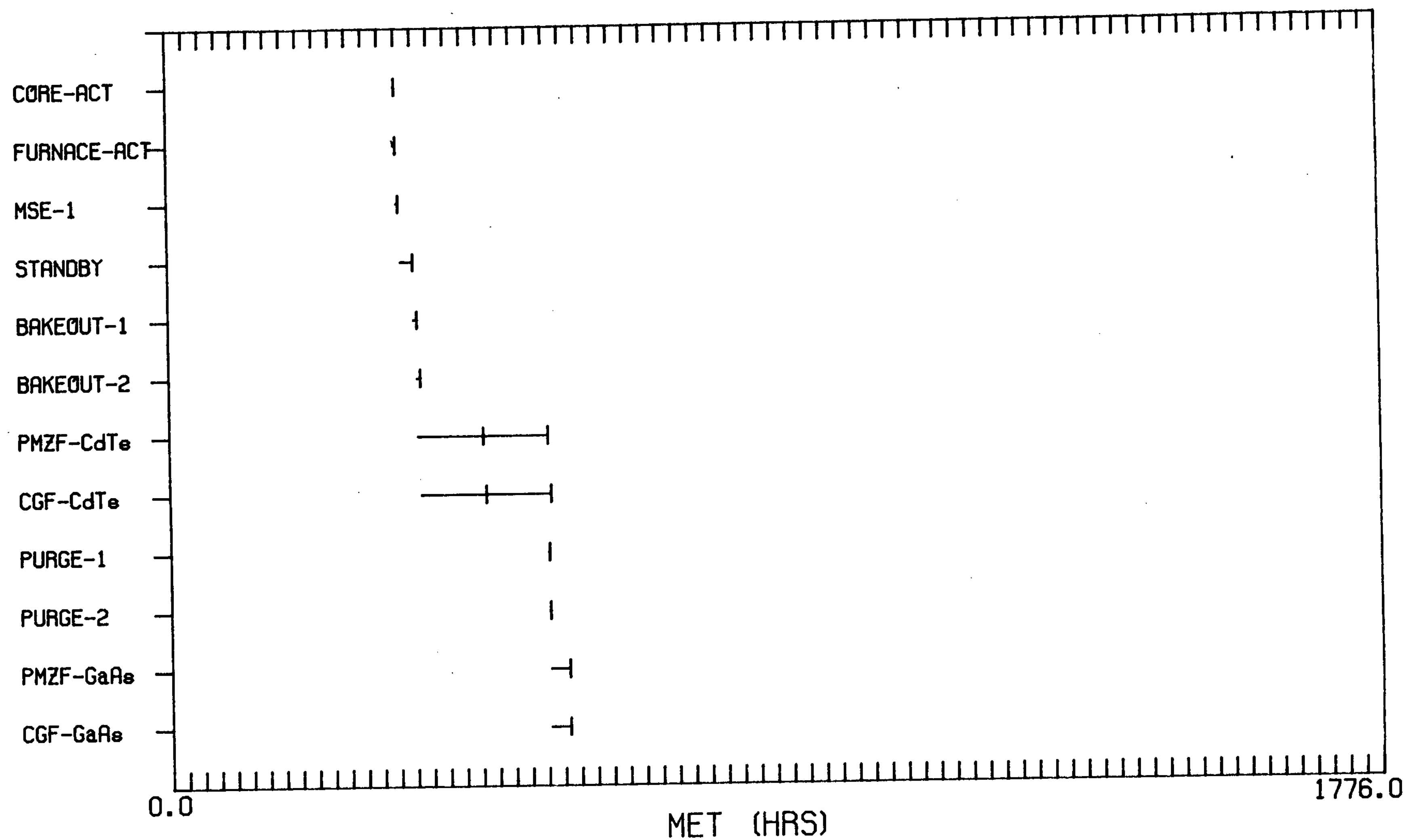
Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in-this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Until the time when resources are allocated for processing, the SSFF will remain in a standby mode. When resources are secured, samples may be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of the system and correct any problems.

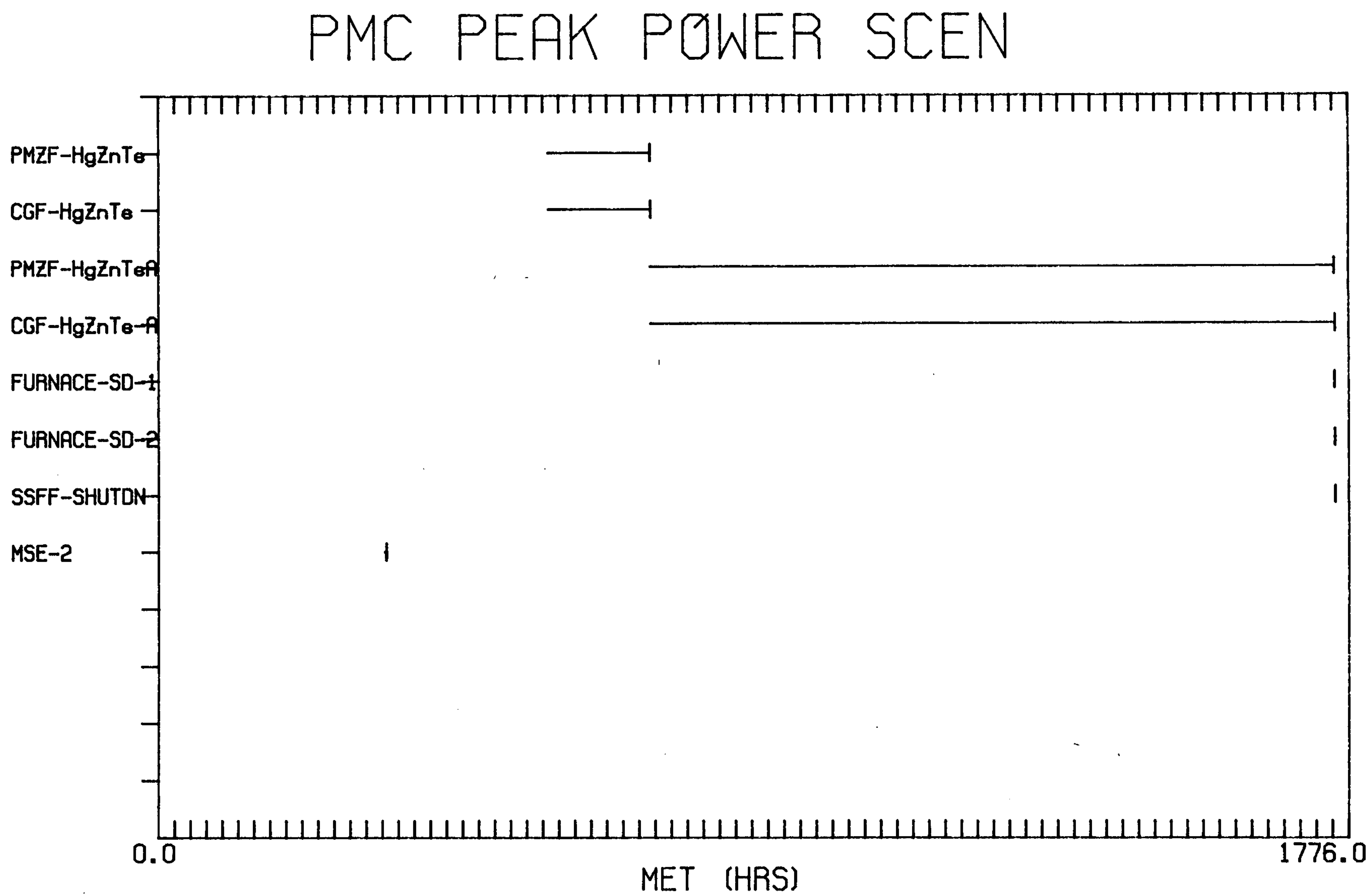
A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first

sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples of CdTe occur next. Upon completion of processing a single sample the carousel within each furnace module will deliver a subsequent sample to be processed. Purging of both furnace modules occurs after the first three samples in the scenario described. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). A sample of GaAs, HgZnTe and an extended sample of HgZnTe are the remaining samples processed within the furnace modules. Upon completion of the entire carousel of samples the Furnace Modules are returned to a standby mode.

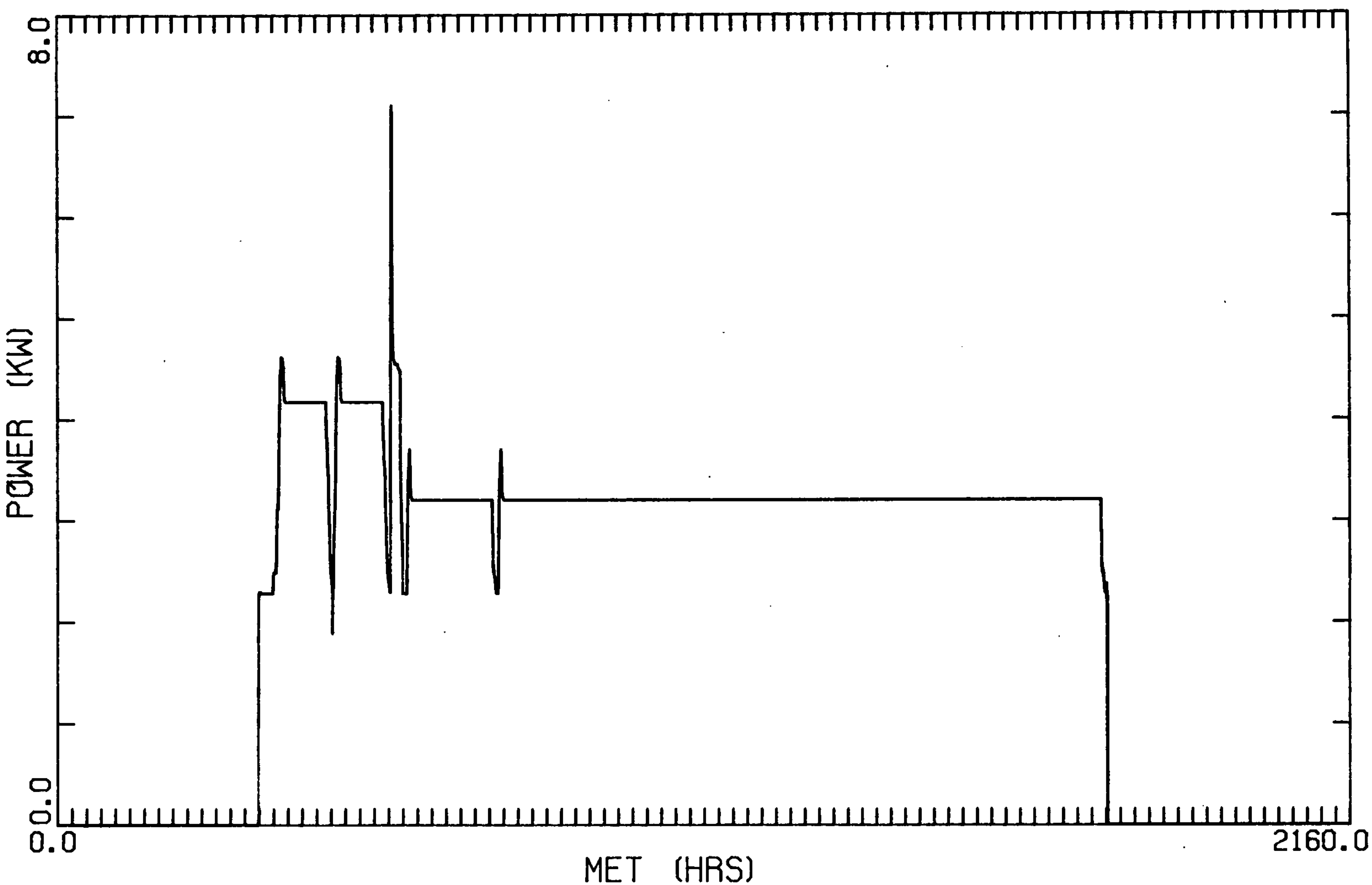
From the standby mode complete shutdown can occur, however with crew available samples may be exchanged. The samples used in this scenario do not allow enough time for another carousel to be processed. Both furnaces will process one carousel apiece within a 90 day mission. Shutdown begins for the each furnace module after the completed carousel. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration requires the SSFF to vent processing gas from the furnace module, configure the TCS into the core rack, and place the furnace into the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

PMC PEAK PØWER SCEN

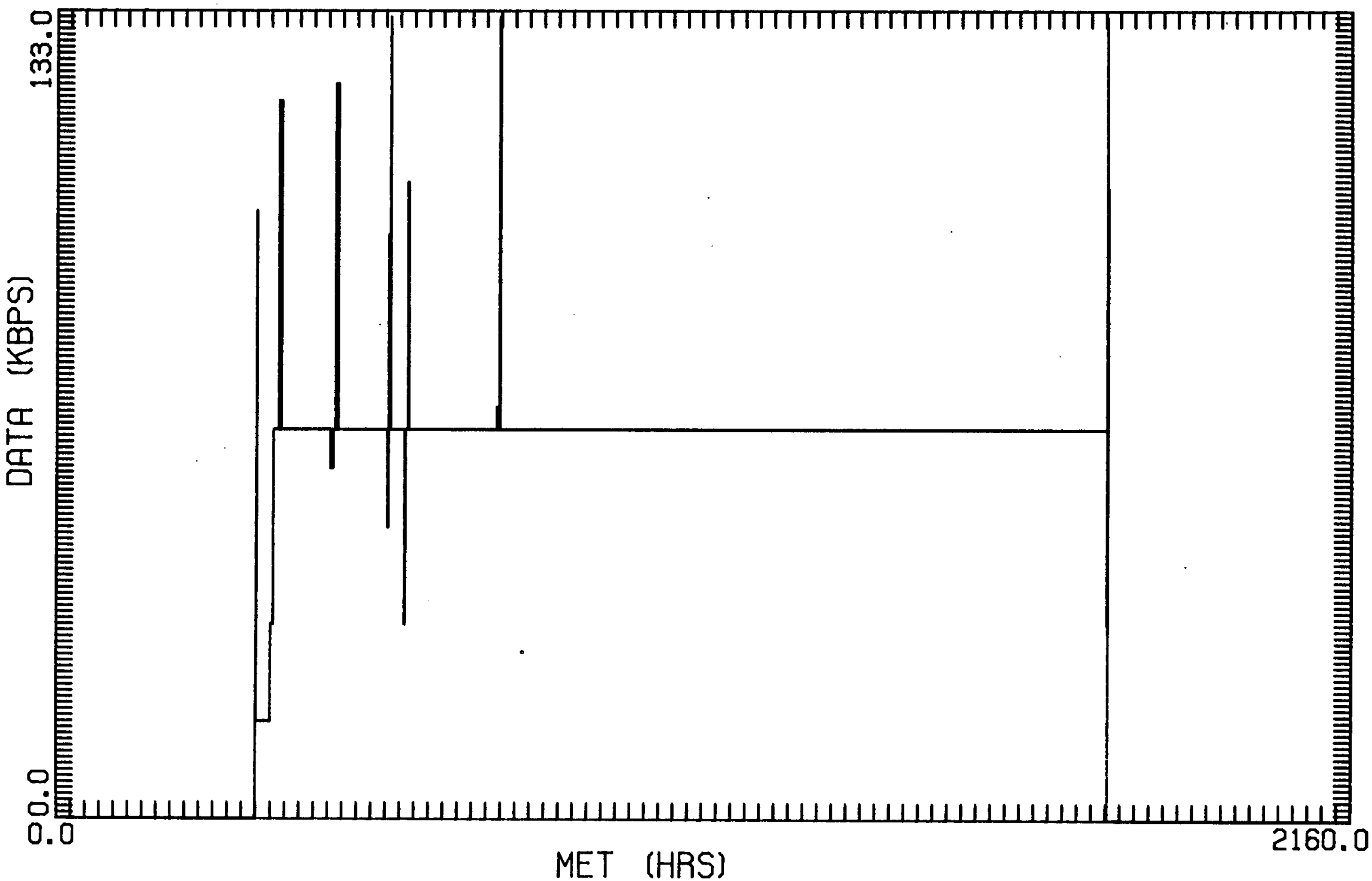



PMC PEAK PØWER SCEN
PMZF-HgZnTe
CGF-HgZnTe
PMZF-HgZnTeA
CGF-HgZnTe-A
FURNACE-SD-1
FURNACE-SD-2
SSFF-SHUTDN
MSE-2
0.0
1776.0
MET (HRS)

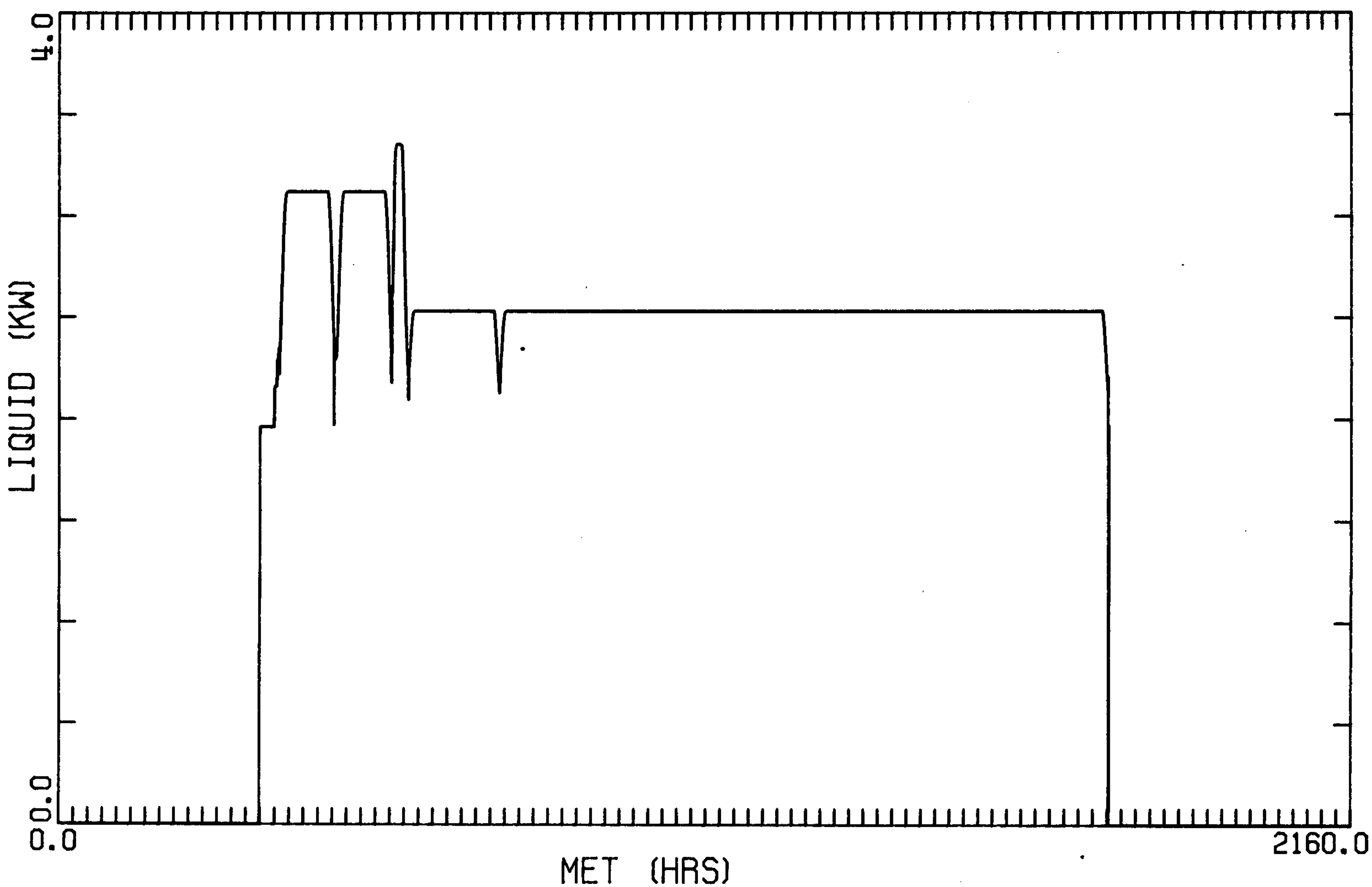
PMC PEAK PØWER SCEN



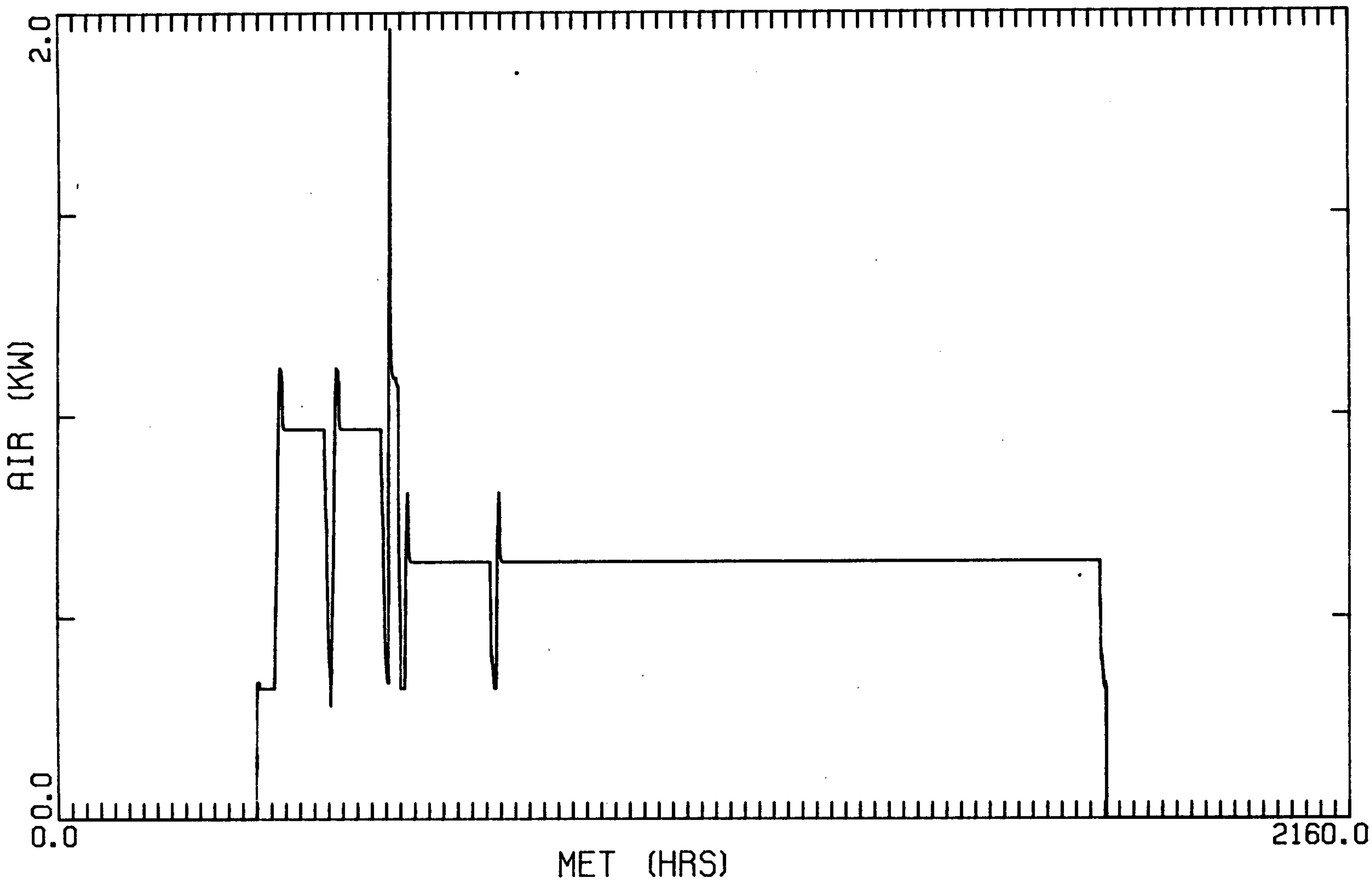
PMC PEAK POWER SCEN



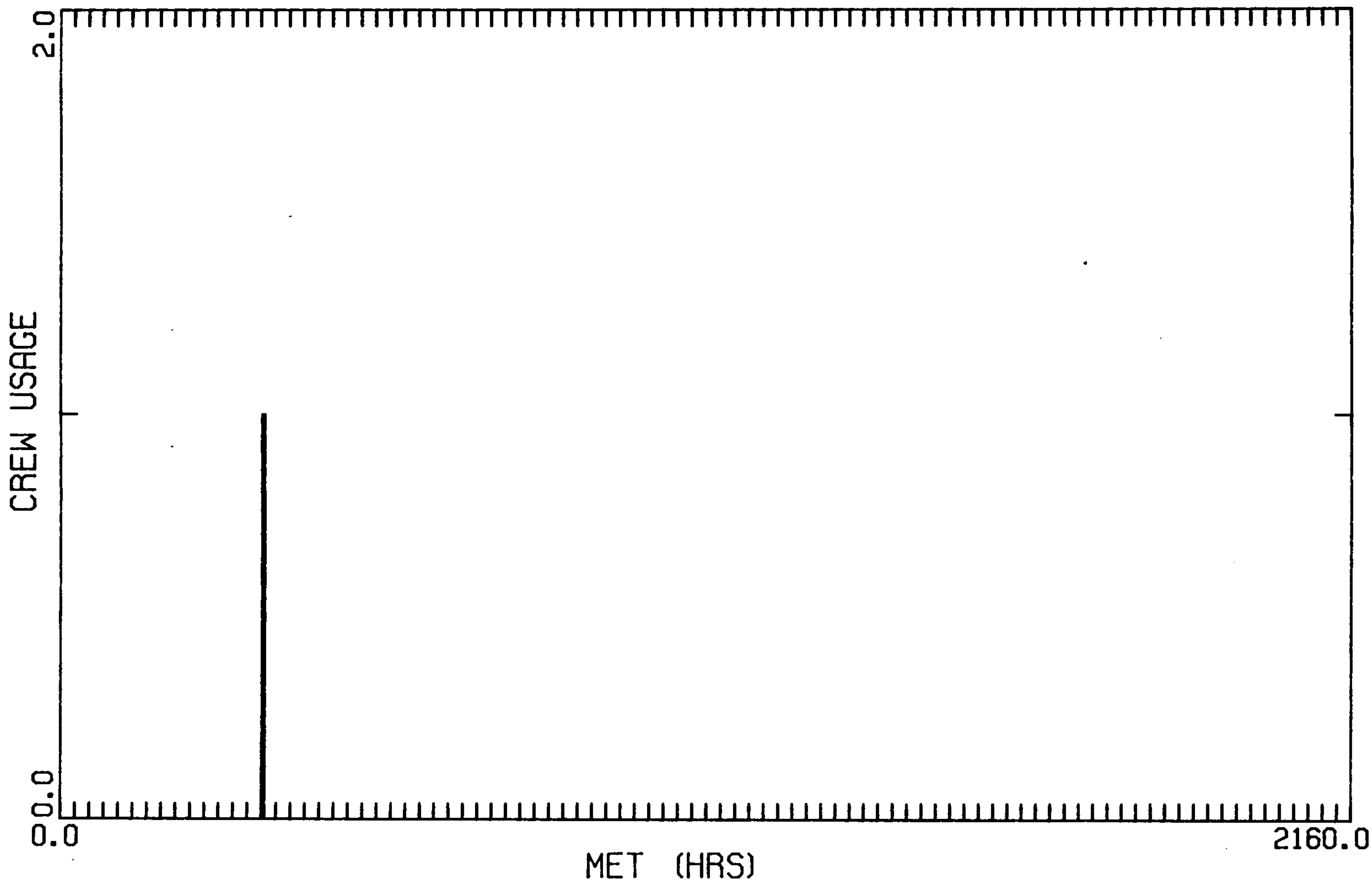
PMC PEAK POWER SCEN



PMC PEAK PØWER SCEN



PMC PEAK POWER SCEN



PMC PEAK POWER SCEN

MODEL	CORE-ACT	INSERTED	FROM	336.00	HRS	TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED	FROM	336.50	HRS	TO	336.95	HRS
MODEL	MSE-1	INSERTED	FROM	336.95	HRS	TO	339.55	HRS
MODEL	MSE-2	INSERTED	FROM	339.55	HRS	TO	342.15	HRS
MODEL	STANDBY	INSERTED	FROM	342.15	HRS	TO	360.00	HRS
MODEL	BAKEOUT-1	INSERTED	FROM	360.00	HRS	TO	365.00	HRS
MODEL	BAKEOUT-2	INSERTED	FROM	364.00	HRS	TO	369.00	HRS
MODEL	PMZF-CdTe	INSERTED	FROM	365.00	HRS	TO	459.90	HRS
MODEL	PMZF-CdTe	INSERTED	FROM	459.92	HRS	TO	554.82	HRS
MODEL	CGF-CdTe	INSERTED	FROM	369.00	HRS	TO	463.90	HRS
MODEL	CGF-CdTe	INSERTED	FROM	463.92	HRS	TO	558.82	HRS
MODEL	PURGE-1	INSERTED	FROM	554.82	HRS	TO	555.59	HRS
MODEL	PURGE-2	INSERTED	FROM	555.58	HRS	TO	556.35	HRS
MODEL	PMZF-GaAs	INSERTED	FROM	556.35	HRS	TO	583.55	HRS
MODEL	CGF-GaAs	INSERTED	FROM	556.35	HRS	TO	583.55	HRS
MODEL	PMZF-HgZnTe	INSERTED	FROM	583.55	HRS	TO	736.25	HRS
MODEL	CGF-HgZnTe	INSERTED	FROM	584.55	HRS	TO	737.26	HRS
MODEL	PMZF-HgZnTeA	INSERTED	FROM	736.25	HRS	TO	1754.83	HRS
MODEL	CGF-HgZnTe-A	INSERTED	FROM	737.25	HRS	TO	1755.84	HRS
MODEL	FURNACE-SD-1	INSERTED	FROM	1754.83	HRS	TO	1754.98	HRS
MODEL	FURNACE-SD-2	INSERTED	FROM	1755.83	HRS	TO	1755.98	HRS
MODEL	SSFF-SHUTDN	INSERTED	FROM	1755.98	HRS	TO	1756.21	HRS

**** MAXIMUM RES1-POWER 7.137 KW
**** MAXIMUM RES2-DATA GENERATION 132.000 KBPS

**** TOTAL ENERGY RES1= 4675.13 KWH
**** TOTAL ENERGY RES2= 89685.00 KBPSH = 40358250 KBytes DATA VOLUME

GROUP 1	ENERGY RES1 = 4675.95	RES2 = 89643.39	CREW TIME (M-Hr) =	2.07
GROUP 2	ENERGY RES1 = 5.95	RES2 = 41.60	CREW TIME (M-Hr) =	2.07
GROUP 3	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 4	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 5	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 6	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 7	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 8	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 9	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 10	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 11	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 12	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 13	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 14	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 15	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 16	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 17	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 18	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 19	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 20	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 3.2918

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE-1	1	1	100.00000000%
MSE-2	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT-1	1	1	100.00000000%
BAKEOUT-2	1	1	100.00000000%
PMZF-CdTe	2	2	100.00000000%
CGF-CdTe	2	2	100.00000000%
PURGE-1	1	1	100.00000000%
PURGE-2	1	1	100.00000000%
PMZF-GaAs	1	1	100.00000000%
CGF-GaAs	1	1	100.00000000%
PMZF-HgZnTe	1	1	100.00000000%
CGF-HgZnTe	1	1	100.00000000%
PMZF-HgZnTeA	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
FURNACE-SD-1	1	1	100.00000000%
FURNACE-SD-2	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

PMC PEAK POWER SCEN

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**** MAXIMUM RES1-LIQUID     3.356 KW
**** MAXIMUM RES2-AIR        1.973 KW


**** TOTAL ENERGY RES1=    3674.00 KWH
**** TOTAL ENERGY RES2=     946.52 KWH
GROUP  1 ENERGY RES1 =     3668.71 RES2 =     945.62 CREW TIME (M-Hr) =        0.00
GROUP  2 ENERGY RES1 =        5.10 RES2 =       0.85 CREW TIME (M-Hr) =        0.00
GROUP  3 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  4 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  5 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  6 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  7 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  8 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP  9 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 10 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 11 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 12 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 13 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 14 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 15 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 16 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 17 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 18 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 19 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
GROUP 20 ENERGY RES1 =        0.00 RES2 =       0.00 CREW TIME (M-Hr) =        0.00
```

PMC REQUESTED SHUTDOWN SCENARIO DESCRIPTION

Scenario #12 exhibits the interruption of one furnace from processing a complete carousel of samples. This scenario includes two samples of CdTe, a sample of HgCdTe, a sample of HgZnTe and an extended sample of HgZnTe repeated for each furnace. This scenario includes a SSFF shutdown procedure for one furnace upon request from SSF. This shutdown request will occur before all of the samples can be processed in that furnace module. The other furnace module will remain operating. This scenario is modeled to demonstrate a possible request from SSF reduce power consumption.

PMC REQUESTED SHUTDOWN SCENARIO OVERVIEW

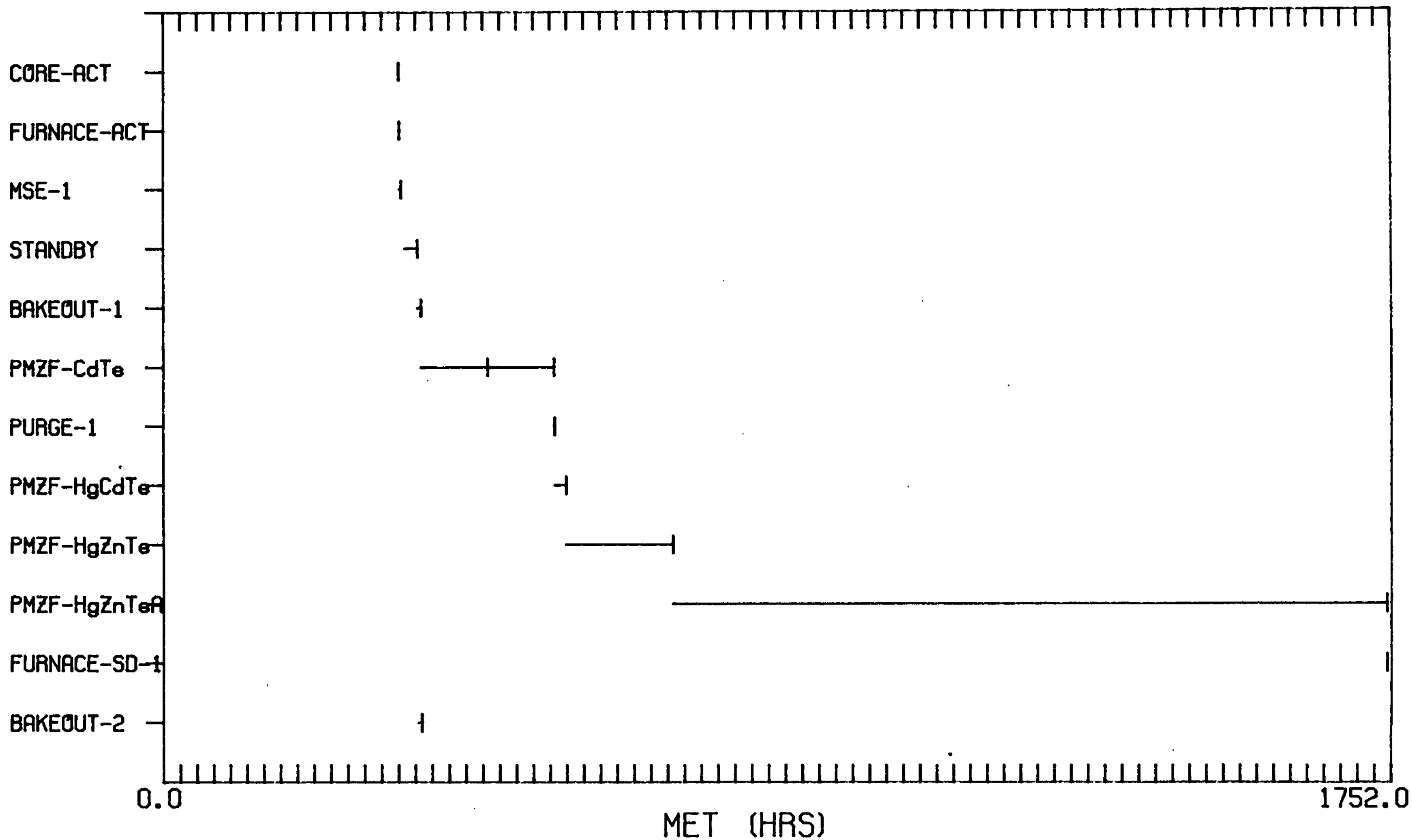
The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Until the time when resources are allocated for processing, the SSFF will remain in a standby mode. When resources are secured, samples may be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of the system and correct any problems.

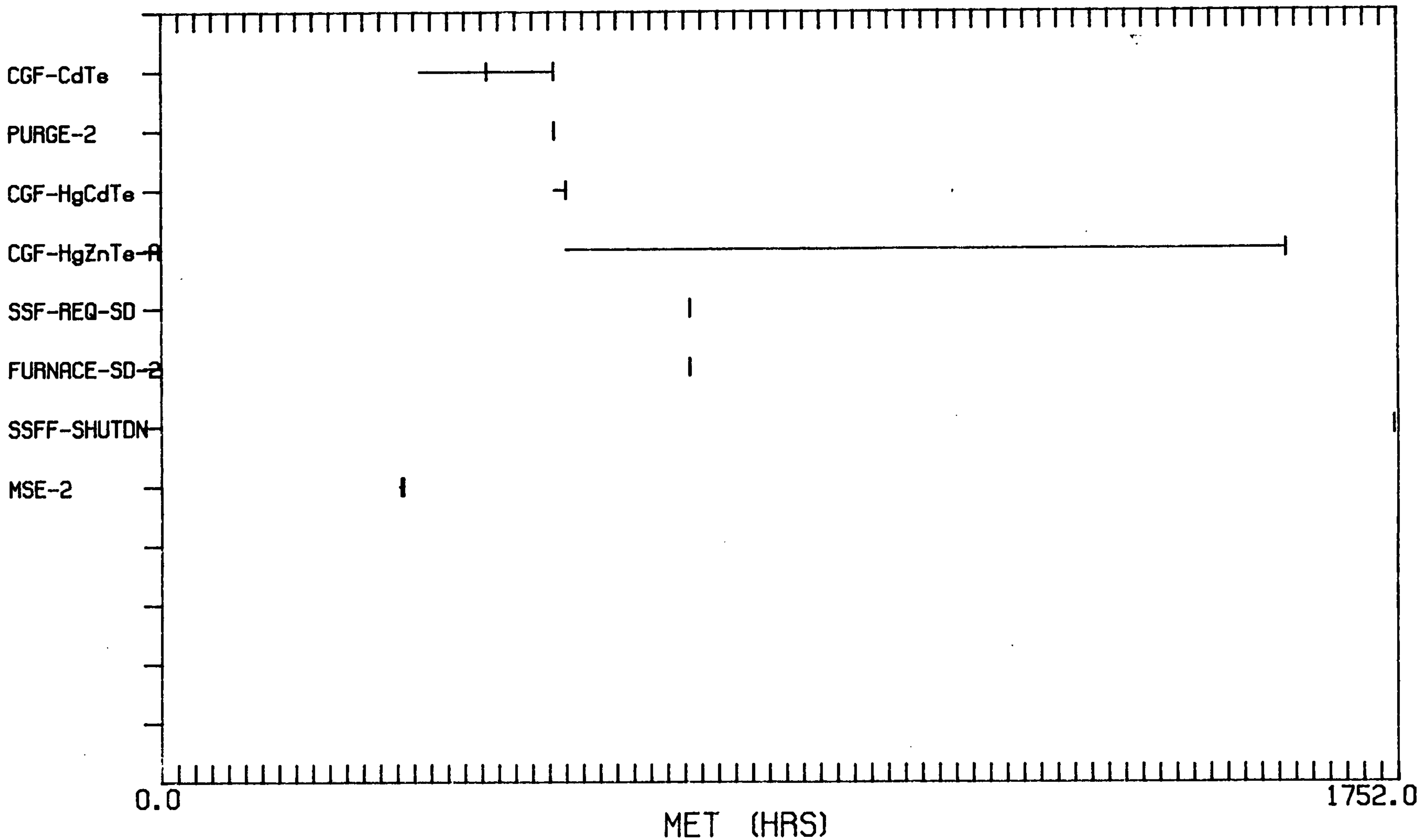
A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a

predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples of CdTe occur next. Upon completion of processing a single sample the carousel within each furnace module will deliver a subsequent sample to be processed. Purging of both furnace modules occurs after the first three samples in the scenario described. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). A sample of HgCdTe, HgZnTe and an extended sample of HgZnTe are the remaining samples processed within the furnace modules. At approximately 175 hours into the processing of HgZnTe, a request from SSF to shutdown Furnace Module #2 is received by the CCU. Shutdown immediately begins for Furnace Module #2. Shutdown occurs through a process of: reconfiguration of the Furnace Module and Furnace Module #2 distributed equipment deactivation. Reconfiguration requires the venting of processing gas from Furnace Module #2, configuring the TCS into the core rack and Furnace Module #1 rack and place the Furnace Module #2 into the home position. This completes shutdown of Furnace module #2, however Furnace Module#1 will remain operating.

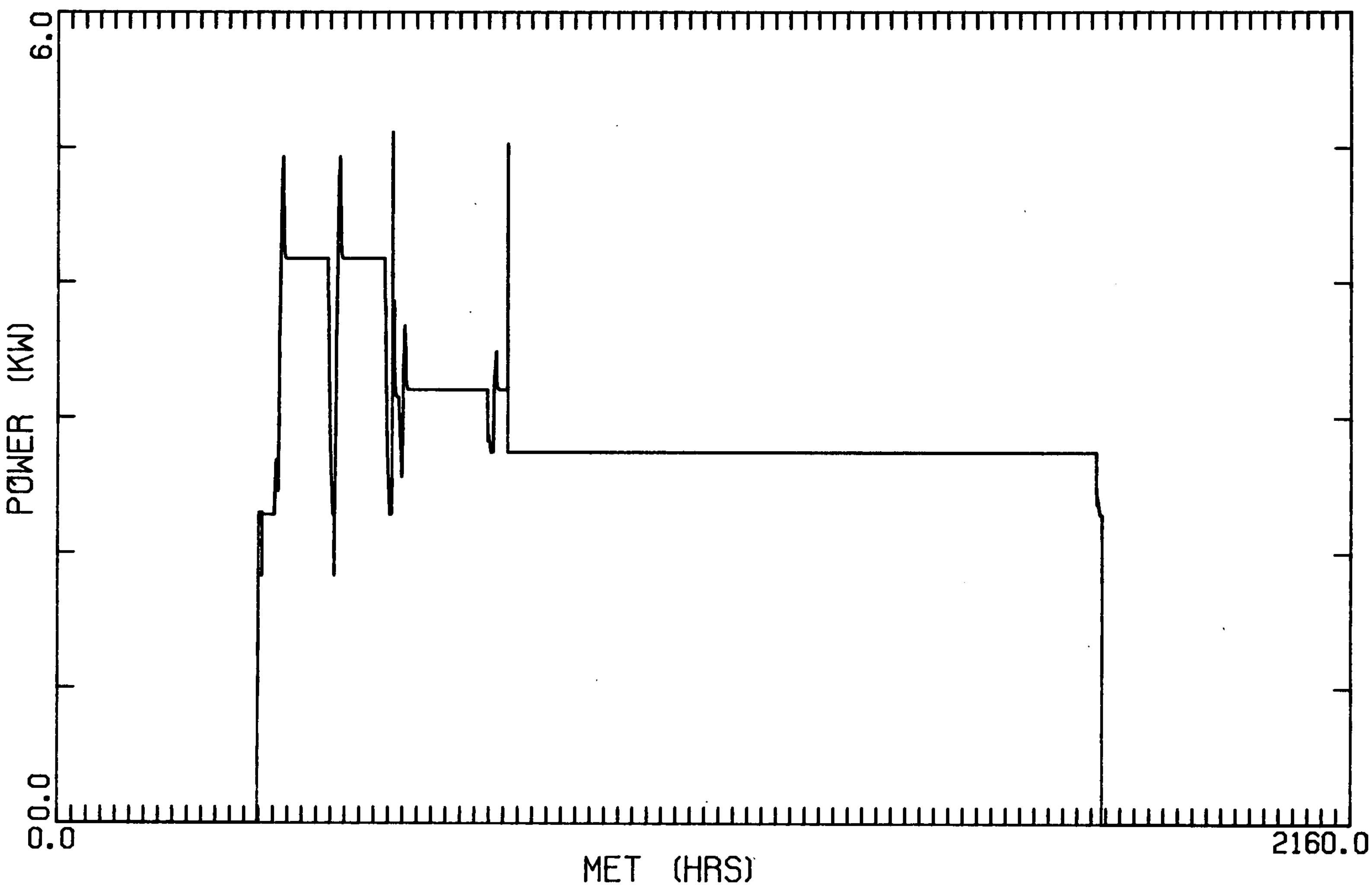
PMC REQUESTED SD



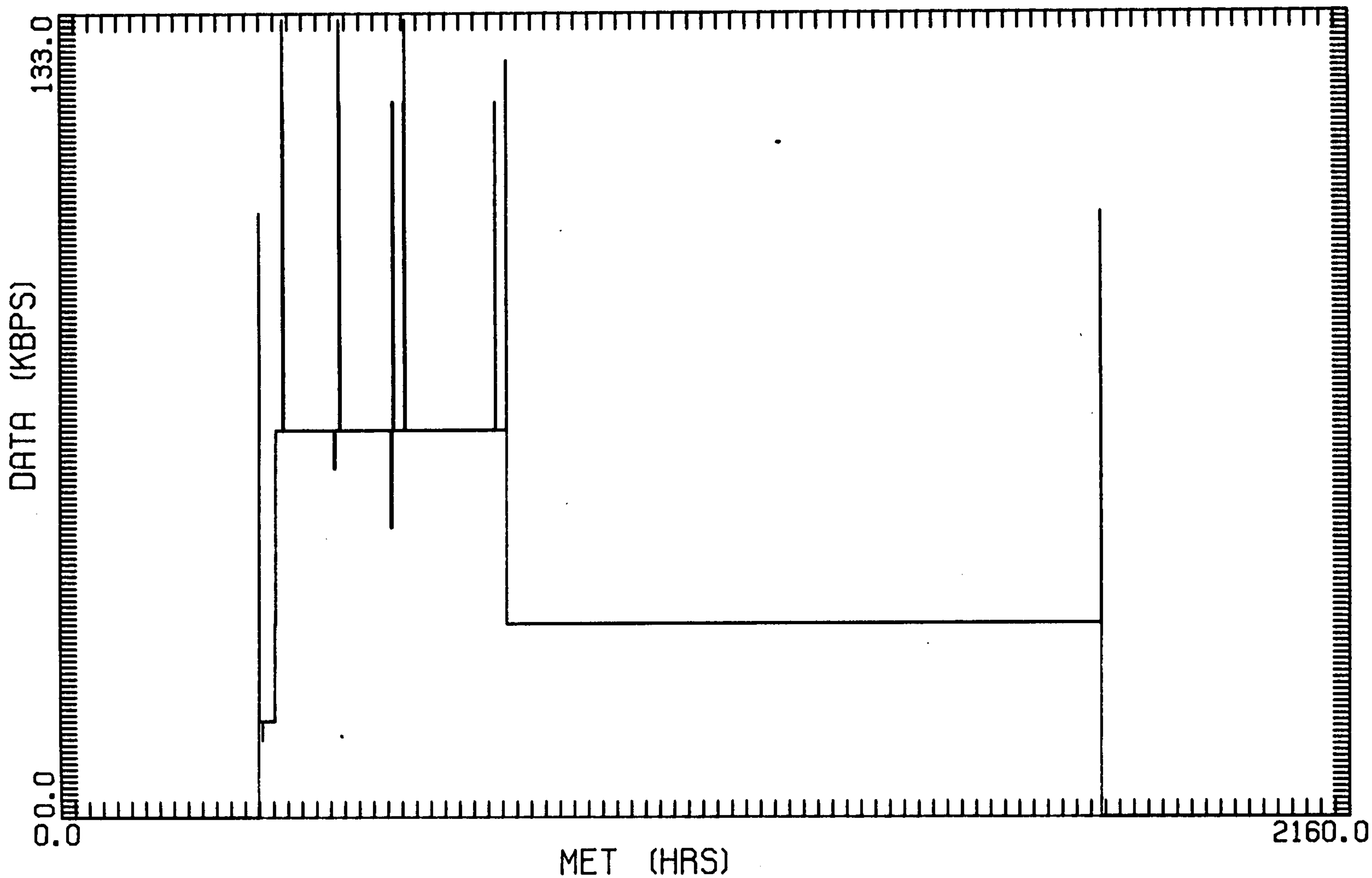
PMC REQUESTED SD



PMC REQUESTED SD



PMC REQUESTED SD



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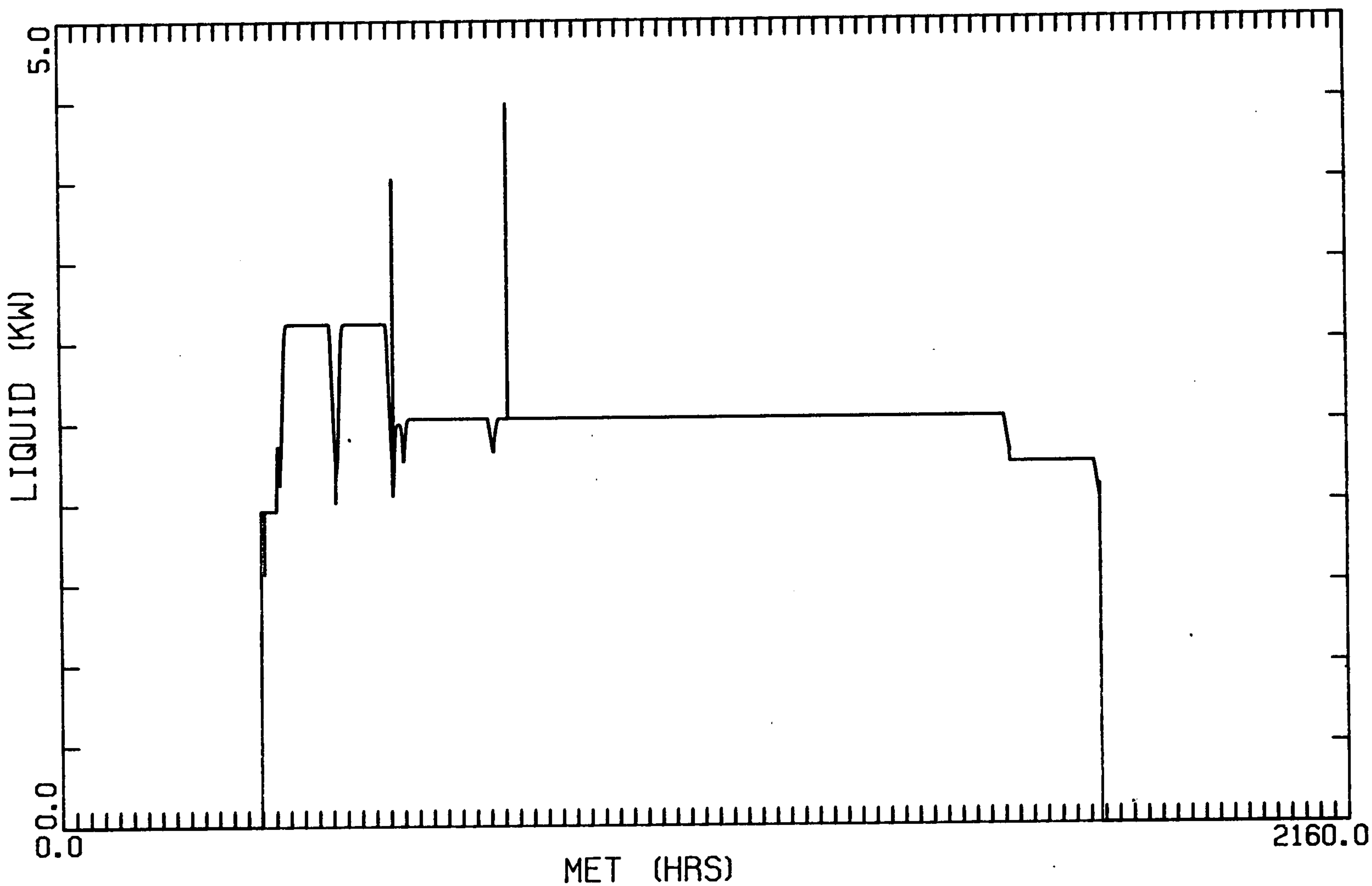

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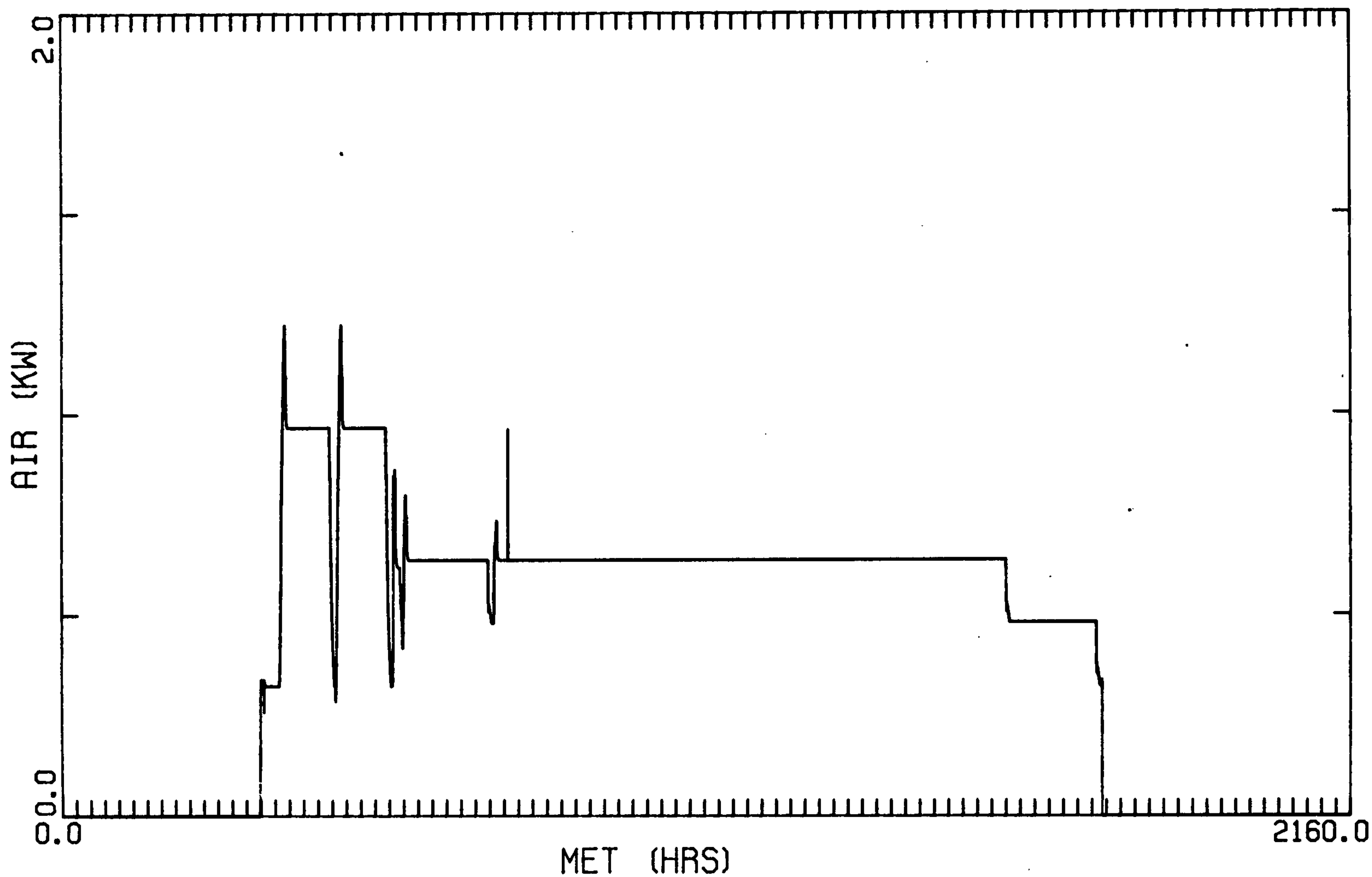

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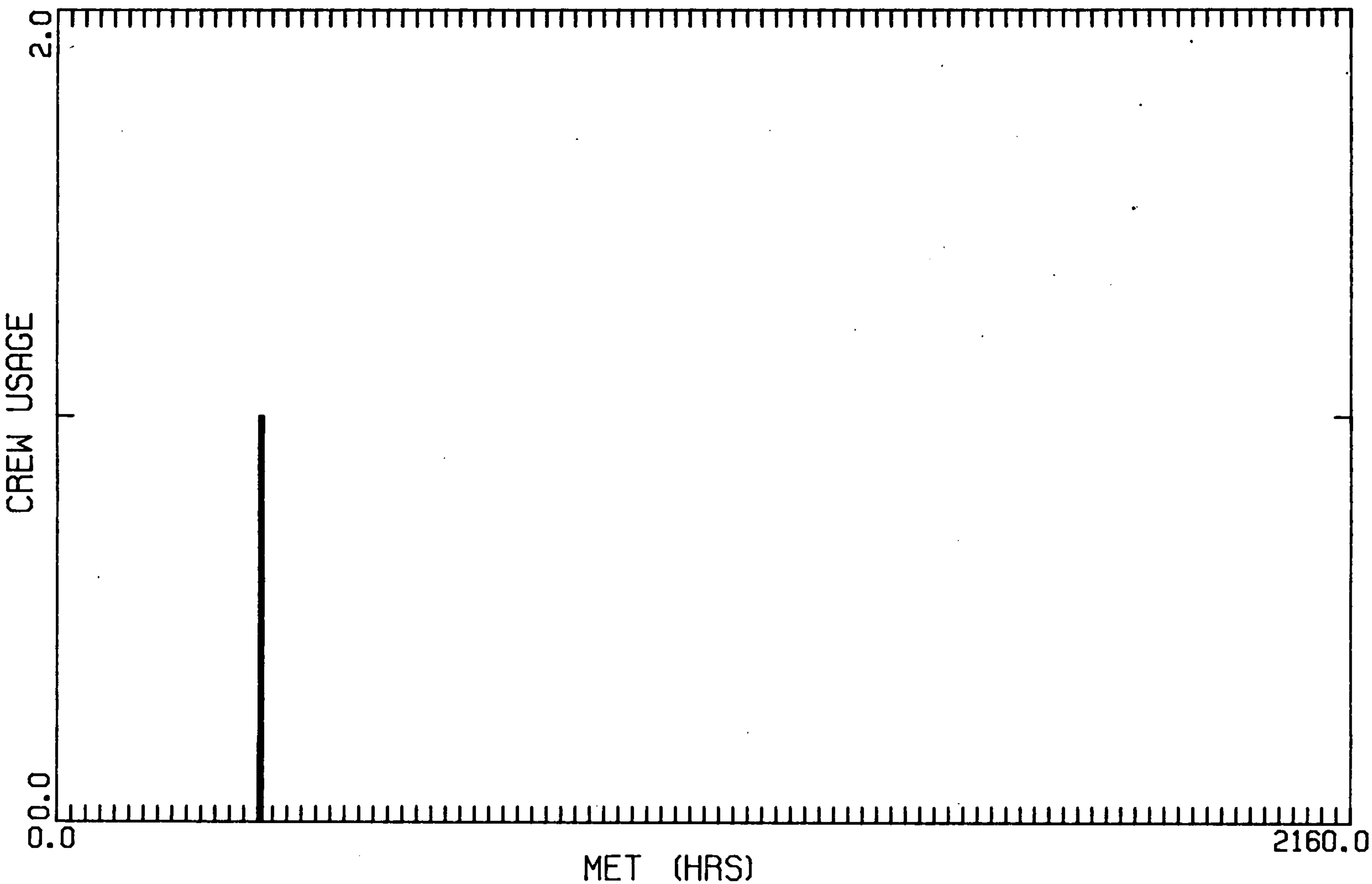


PMC REQUESTED SD

MODEL	CORE-ACT	INSERTED FROM	336.00	HRS TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED FROM	336.50	HRS TO	336.95	HRS
MODEL	MSE-1	INSERTED FROM	336.95	HRS TO	339.55	HRS
MODEL	MSE-2	INSERTED FROM	339.55	HRS TO	342.15	HRS
MODEL	STANDBY	INSERTED FROM	342.15	HRS TO	360.00	HRS
MODEL	BAKEOUT-1	INSERTED FROM	360.00	HRS TO	365.00	HRS
MODEL	PMZF-CdTe	INSERTED FROM	365.00	HRS TO	459.90	HRS
MODEL	PMZF-CdTe	INSERTED FROM	459.92	HRS TO	554.82	HRS
MODEL	PURGE-1	INSERTED FROM	554.82	HRS TO	555.58	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	555.58	HRS TO	572.08	HRS
MODEL	PMZF-HgZnTe	INSERTED FROM	572.08	HRS TO	724.78	HRS
MODEL	PMZF-HgZnTeA	INSERTED FROM	724.78	HRS TO	1743.37	HRS
MODEL	FURNACE-SD-1	INSERTED FROM	1743.37	HRS TO	1743.52	HRS
MODEL	BAKEOUT-2	INSERTED FROM	364.00	HRS TO	369.00	HRS
MODEL	CGF-CdTe	INSERTED FROM	369.00	HRS TO	463.90	HRS
MODEL	CGF-CdTe	INSERTED FROM	463.92	HRS TO	558.82	HRS
MODEL	PURGE-2	INSERTED FROM	558.82	HRS TO	559.58	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	559.58	HRS TO	576.08	HRS
MODEL	CGF-HgZnTe-A	INSERTED FROM	576.08	HRS TO	751.34	HRS
MODEL	SSF-REQ-SD	INSERTED FROM	751.34	HRS TO	751.36	HRS
MODEL	FURNACE-SD-2	INSERTED FROM	751.36	HRS TO	751.51	HRS
MODEL	SSFF-SHUTDN	INSERTED FROM	1743.52	HRS TO	1743.75	HRS

**** MAXIMUM RES1-POWER 5.129 KW
**** MAXIMUM RES2-DATA GENERATION 132.000 KBPS

**** TOTAL ENERGY RES1= 4178.24 KWH
**** TOTAL ENERGY RES2= 57161.59 KBPSH = 25722716 KBytes DATA VOLUME

GROUP 1	ENERGY RES1 =	4178.24	RES2 =	57161.59	CREW TIME (M-Hr) = 4.13
GROUP 2	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 3	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00
GROUP 20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) = 0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 2.9625

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE-1	1	1	100.00000000%
MSE-2	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT-1	1	1	100.00000000%
PMZF-CdTe	2	2	100.00000000%
PURGE-1	1	1	100.00000000%
PMZF-HgCdTe	1	1	100.00000000%
PMZF-HgZnTe	1	1	100.00000000%
PMZF-HgZnTeA	1	1	100.00000000%
FURNACE-SD-1	1	1	100.00000000%
BAKEOUT-2	1	1	100.00000000%
CGF-CdTe	2	2	100.00000000%
PURGE-2	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
SSF-REQ-SD	1	1	100.00000000%
FURNACE-SD-2	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

PMC REQUESTED SD

**** MAXIMUM RES1-LIQUID 4.208 KW
**** MAXIMUM RES2-AIR 1.118 KW

**** TOTAL ENERGY RES1= 3590.74 KWH
**** TOTAL ENERGY RES2= 909.90 KWH

GROUP 1 ENERGY RES1 =	3589.71 RES2 =	909.85 CREW TIME (M-Hr) =	0.00
GROUP 2 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 3 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 4 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 5 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 6 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 7 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 8 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 9 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 10 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 11 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 12 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 13 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 14 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 15 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 16 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 17 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 18 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 19 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 20 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00

PMC NON-REQUESTED SHUTDOWN SCENARIO DESCRIPTION

Scenario #13 demonstrates possible equipment safing for SSFF. Both furnaces are interrupted as a result of a loss of power to one SSF bus. Both furnaces process the same type samples that were processed in Scenario #11.

PMC NON-REQUESTED SHUTDOWN SCENARIO OVERVIEW

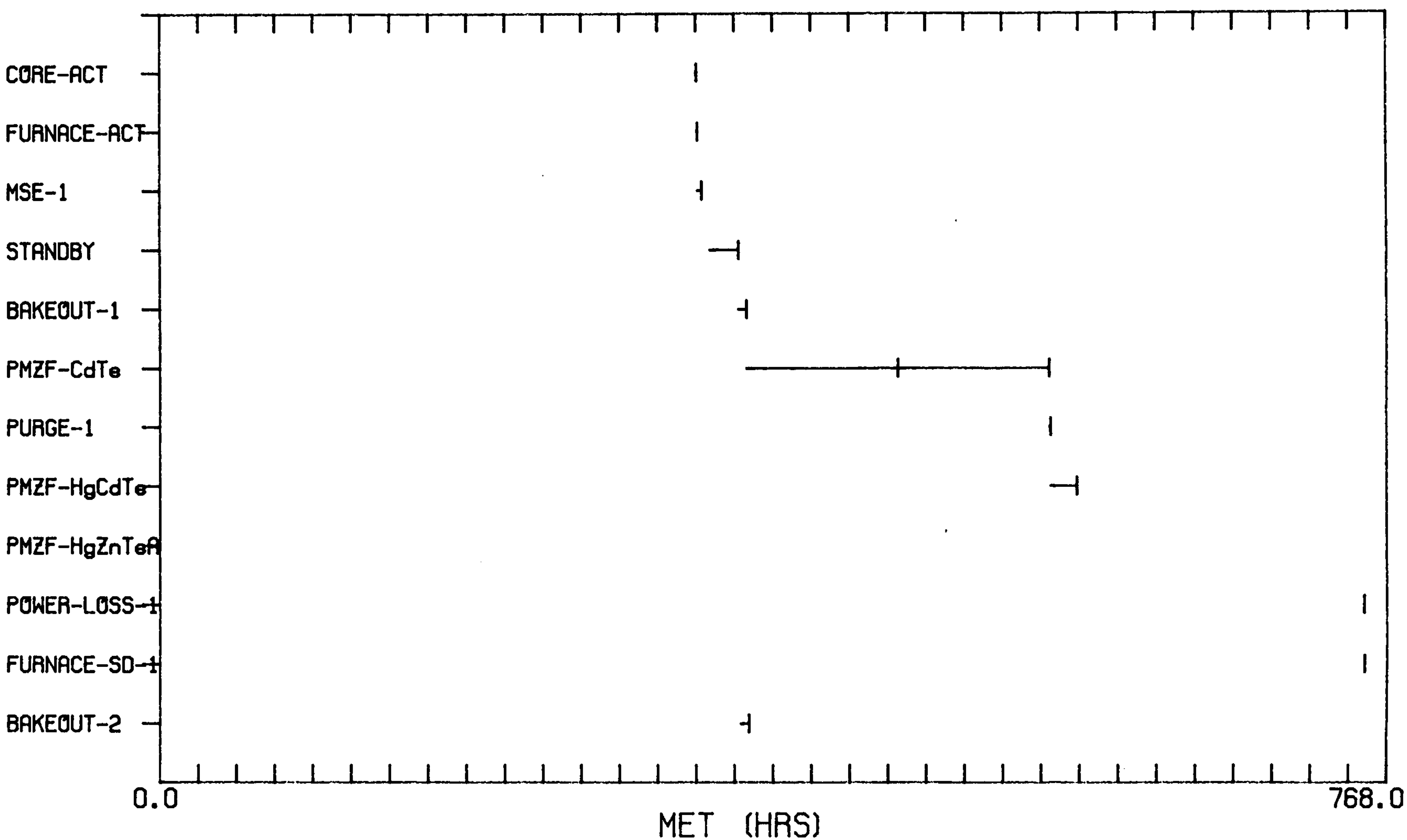
The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Until the time when resources are allocated for processing, the SSFF will remain in a standby mode. When resources are secured, samples may be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of the system and correct any problems.

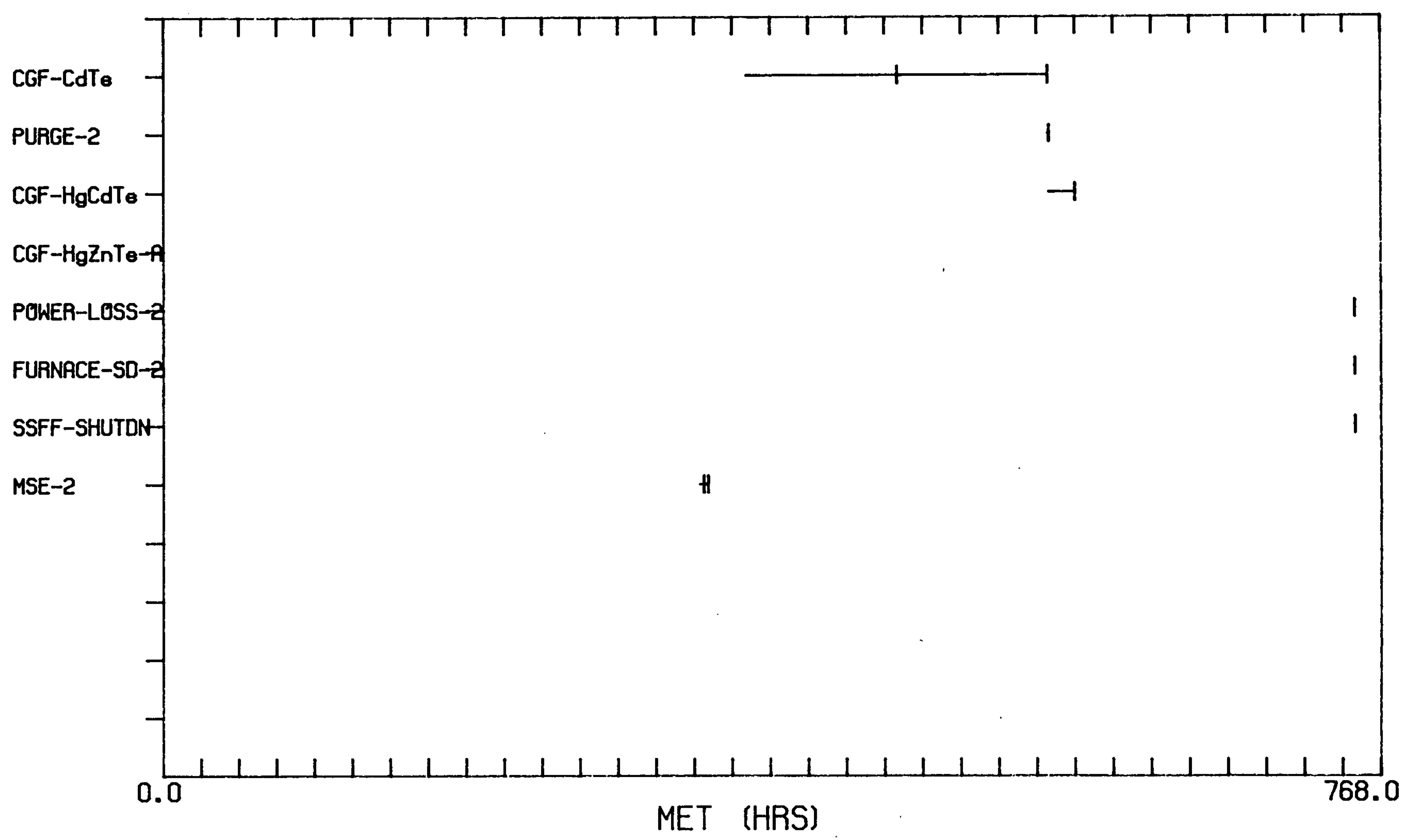
A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples of CdTe occur next. Upon completion of processing a single sample the carousel within each furnace module will deliver a subsequent sample to be processed. Purging of both furnace modules occurs after the first three samples in the scenario described. Depending on the

degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). A sample of HgCdTe, HgZnTe and an extended sample of HgZnTe are the remaining samples processed within the furnace modules. At approximately 175 hours into the processing of the HgZnTe extended sample, power is lost on one power bus from SSF. The SSFF is capable of operation with the one remaining power bus, however because of safety requirements the shutdown of both Furnace Modules is implemented. After verifying only one power bus remains, the CCU immediately terminates power to both Furnace Modules and the shutdown procedure begins. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation in both furnace module racks and deactivation of core equipment. Reconfiguration of SSFF requires the facility to vent processing gases from both furnace modules and to place the furnaces into the home position. The TCS can be configured to aid in cooling the furnace modules for a short time. The SSFF is capable of operating the essential equipment on one power bus to allow for this procedure. Therefore, on SSF approval, the possibility remains that essential equipment could continue to run and aid in monitoring and cooling of the unpowered Furnace Modules. If continued operation is denied, deactivation of the all distributed equipment occurs followed by deactivation of the core equipment. In the shutdown of the core equipment, the TCS pump package and CCU will be the last components shutdown. Upon notification from the SSFF to suspend resources supplied by SSF, the Furnace Facility is completely shutdown.

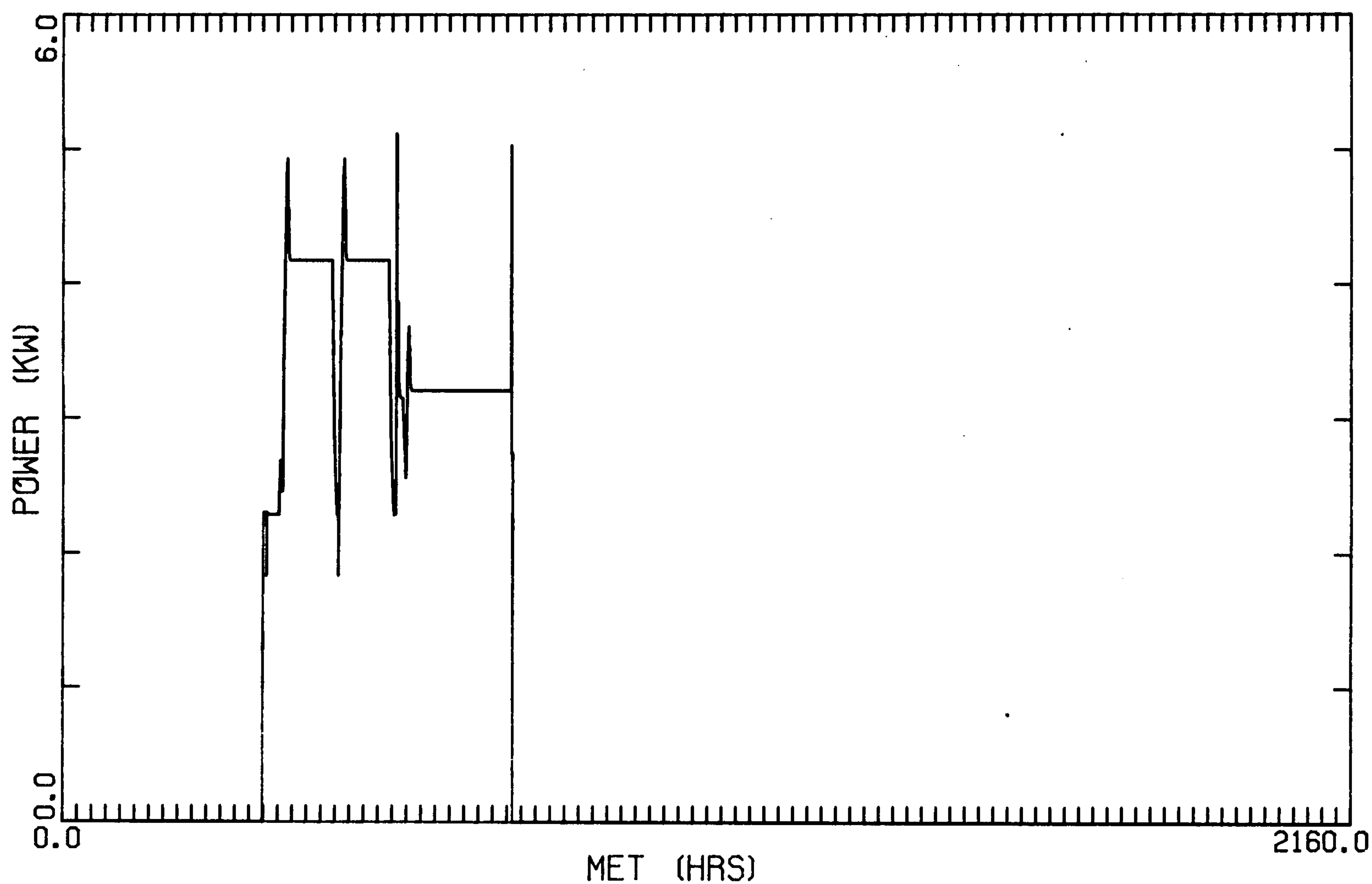
PMC POWER LOSS



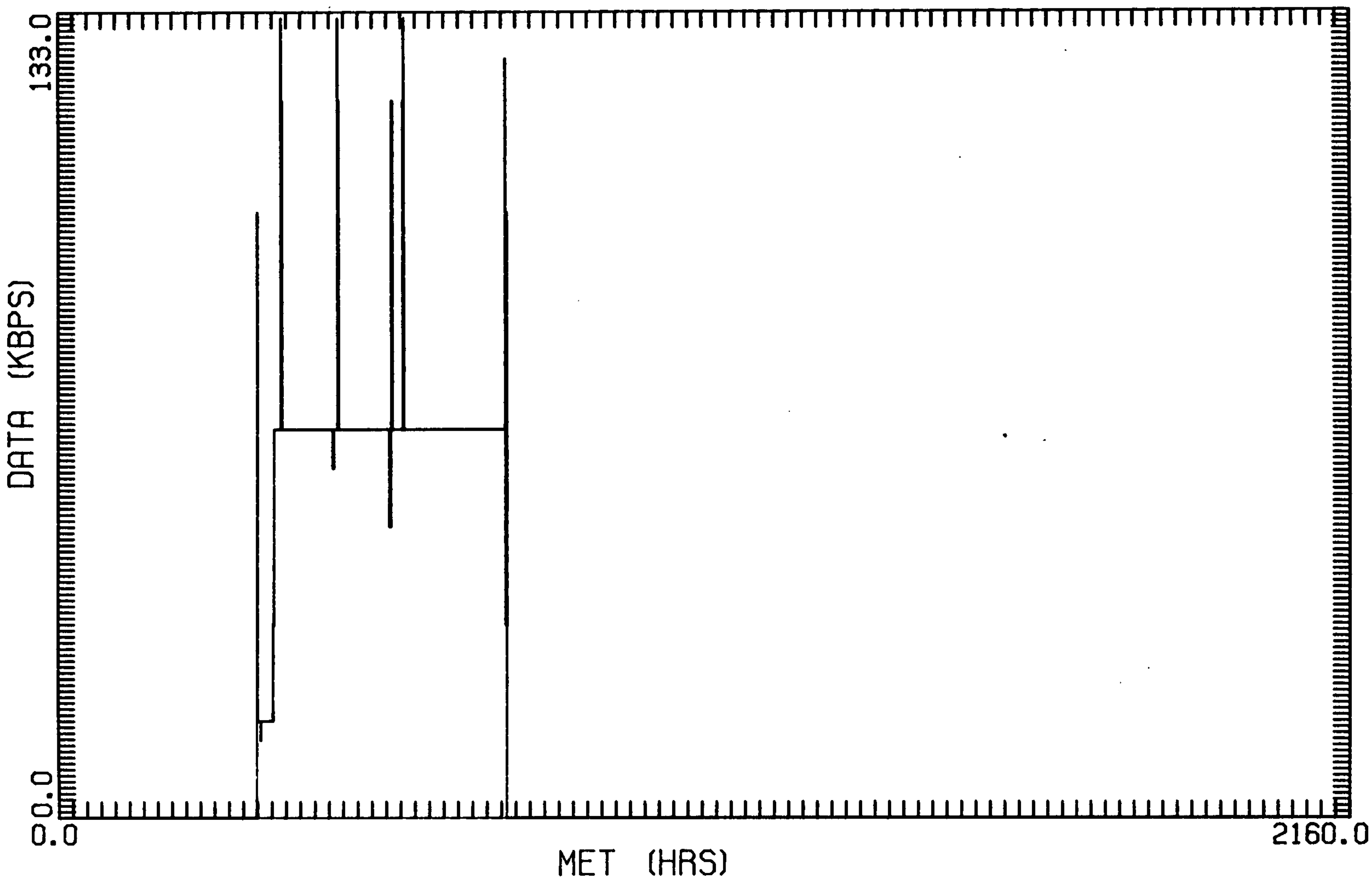
PMC POWER LØSS

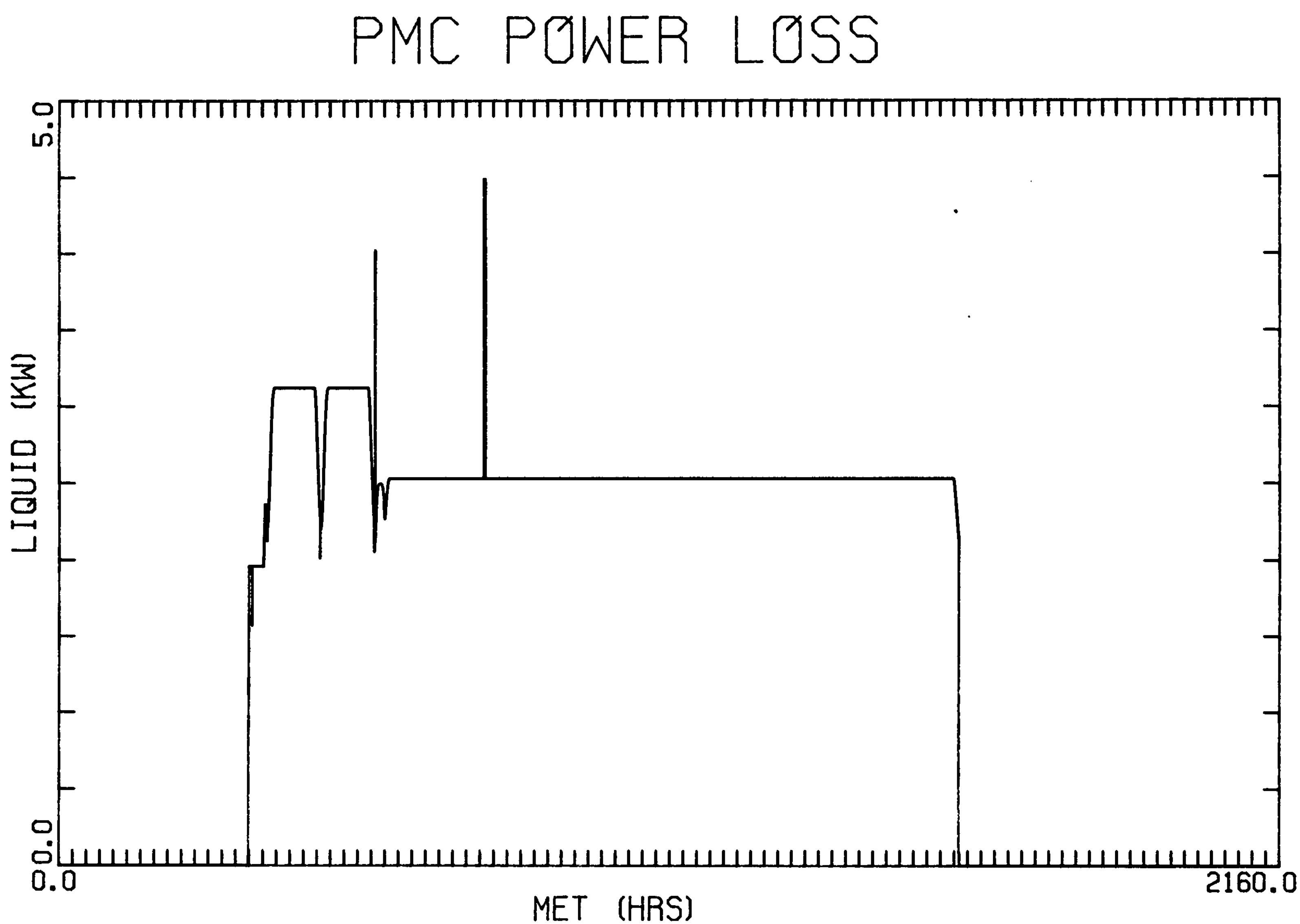


PMC POWER LOSS

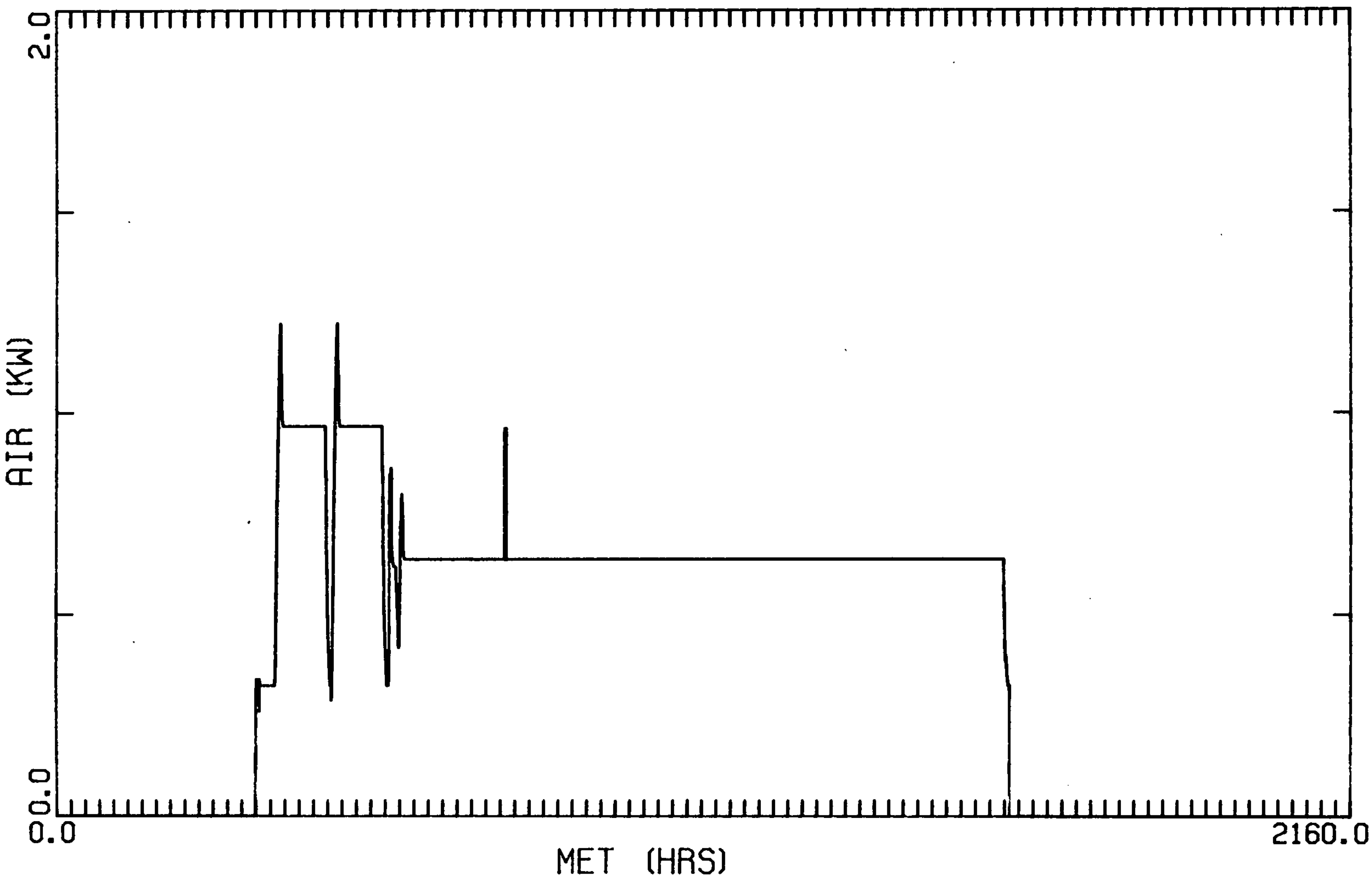


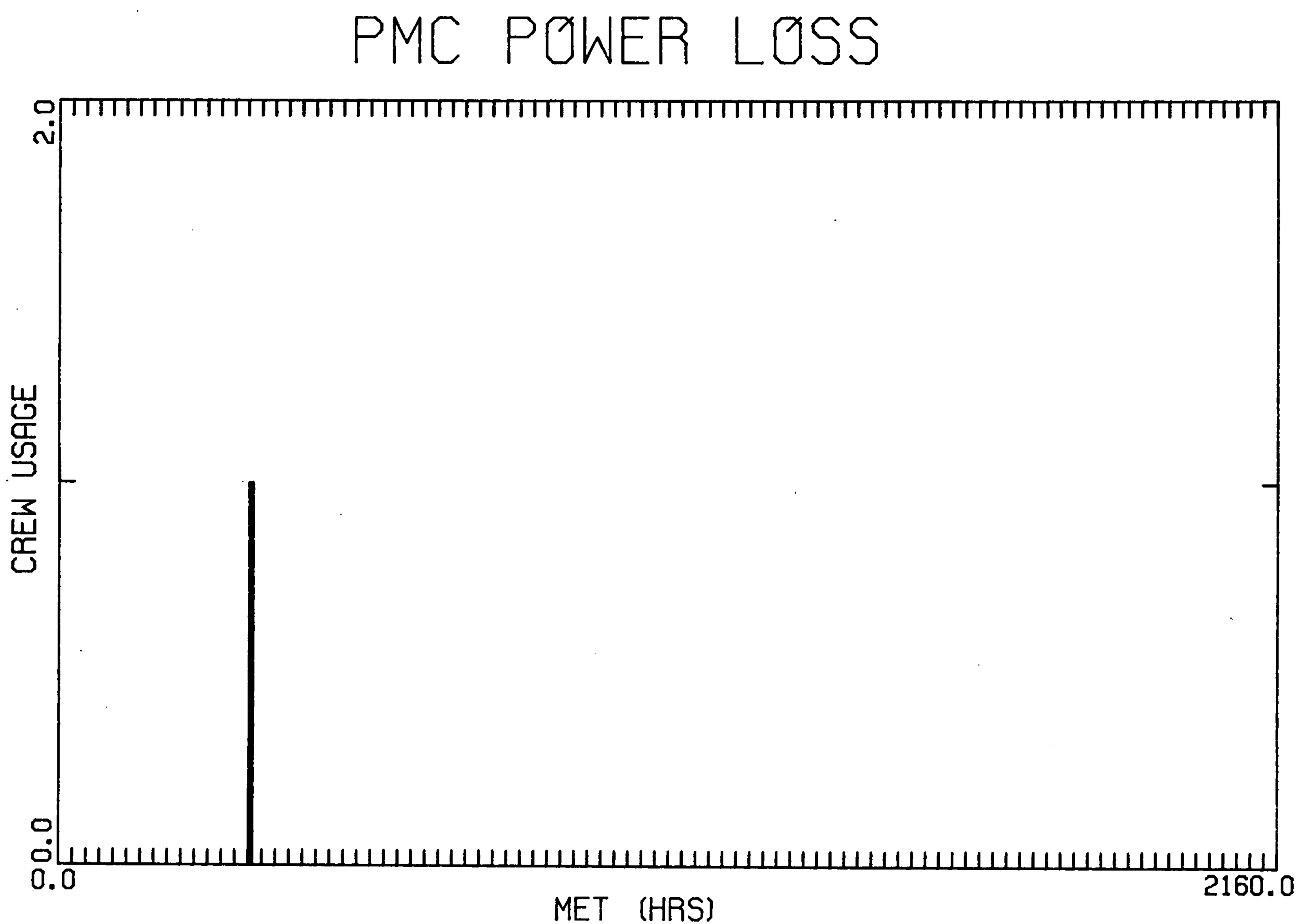
PMC PØWER LØSS




PMC POWER LØSS
5.0
LIQUID (KW)
0.0
0.0
MET (HRS)
2160.0

PMC POWER LOSS




PMC POWER LØSS
2.0
CREW USAGE
0.0
0.0
2160.0
MET (HRS)

PMC POWER LOSS

MODEL	CORE-ACT	INSERTED FROM	336.00	HRS TO	336.50	HRS
MODEL	FURNACE-ACT	INSERTED FROM	336.50	HRS TO	336.95	HRS
MODEL	MSE-1	INSERTED FROM	336.95	HRS TO	339.55	HRS
MODEL	MSE-2	INSERTED FROM	339.55	HRS TO	342.15	HRS
MODEL	STANDBY	INSERTED FROM	342.15	HRS TO	360.00	HRS
MODEL	BAKEOUT-1	INSERTED FROM	360.00	HRS TO	365.00	HRS
MODEL	PMZF-CdTe	INSERTED FROM	365.00	HRS TO	459.90	HRS
MODEL	PMZF-CdTe	INSERTED FROM	459.92	HRS TO	554.82	HRS
MODEL	PURGE-1	INSERTED FROM	554.82	HRS TO	555.58	HRS
MODEL	PMZF-HgCdTe	INSERTED FROM	555.58	HRS TO	572.08	HRS
MODEL	PMZF-HgZnTeA	INSERTED FROM	572.08	HRS TO	751.33	HRS
MODEL	POWER-LOSS-1	INSERTED FROM	751.33	HRS TO	751.35	HRS
MODEL	FURNACE-SD-1	INSERTED FROM	751.35	HRS TO	751.50	HRS
MODEL	BAKEOUT-2	INSERTED FROM	364.00	HRS TO	369.00	HRS
MODEL	CGF-CdTe	INSERTED FROM	369.00	HRS TO	463.90	HRS
MODEL	CGF-CdTe	INSERTED FROM	463.92	HRS TO	558.82	HRS
MODEL	PURGE-2	INSERTED FROM	558.82	HRS TO	559.58	HRS
MODEL	CGF-HgCdTe	INSERTED FROM	559.58	HRS TO	576.08	HRS
MODEL	CGF-HgZnTe-A	INSERTED FROM	576.08	HRS TO	751.34	HRS
MODEL	POWER-LOSS-2	INSERTED FROM	751.34	HRS TO	751.36	HRS
MODEL	FURNACE-SD-2	INSERTED FROM	751.36	HRS TO	751.51	HRS
MODEL	SSFF-SHUTDN	INSERTED FROM	751.51	HRS TO	751.74	HRS

**** MAXIMUM RES1-POWER 5.129 KW
**** MAXIMUM RES2-DATA GENERATION 132.000 KBPS

**** TOTAL ENERGY RES1= 1459.51 KWH
**** TOTAL ENERGY RES2= 25409.72 KBPSH = 11434374 KBytes DATA VOLUME

GROUP 1	ENERGY RES1 = 1459.51	RES2 = 25409.72	CREW TIME (M-Hr) =	6.20
GROUP 2	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 3	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 4	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 5	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 6	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 7	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 8	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 9	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 10	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 11	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 12	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 13	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 14	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 15	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 16	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 17	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 18	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 19	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00
GROUP 20	ENERGY RES1 = 0.00	RES2 = 0.00	CREW TIME (M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 3.4952

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE-1	1	1	100.00000000%
MSE-2	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT-1	1	1	100.00000000%
PMZF-CdTe	2	2	100.00000000%
PURGE-1	1	1	100.00000000%
PMZF-HgCdTe	1	1	100.00000000%
PMZF-HgZnTeA	1	1	100.00000000%
POWER-LOSS-1	1	1	100.00000000%
FURNACE-SD-1	1	1	100.00000000%
BAKEOUT-2	1	1	100.00000000%
CGF-CdTe	2	2	100.00000000%
PURGE-2	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
POWER-LOSS-2	1	1	100.00000000%
FURNACE-SD-2	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

PMC POWER LOSS

**** MAXIMUM RES1-LIQUID 4.492 KW
**** MAXIMUM RES2-AIR 1.225 KW

**** TOTAL ENERGY RES1= 3253.91 KWH
**** TOTAL ENERGY RES2= 838.53 KWH

GROUP 1	ENERGY RES1 =	3242.61	RES2 =	836.76	CREW TIME (M-Hr) =	0.00
GROUP 2	ENERGY RES1 =	10.20	RES2 =	1.71	CREW TIME (M-Hr) =	0.00
GROUP 3	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00
GROUP 20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME (M-Hr) =	0.00

PMC REPROGRAMMING TASK SCENARIO DESCRIPTION

Scenario # 14 displays a short delayed time increment for the possible reprogramming of furnace parameters. One furnace exhibits a reprogramming task while the other furnace operates normally. The reprogramming task occurs after completion of the forth sample in Furnace Module #1. The type of samples processed are the same as in Scenario #9.

PMC REPROGRAMMING TASK SCENARIO OVERVIEW

The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

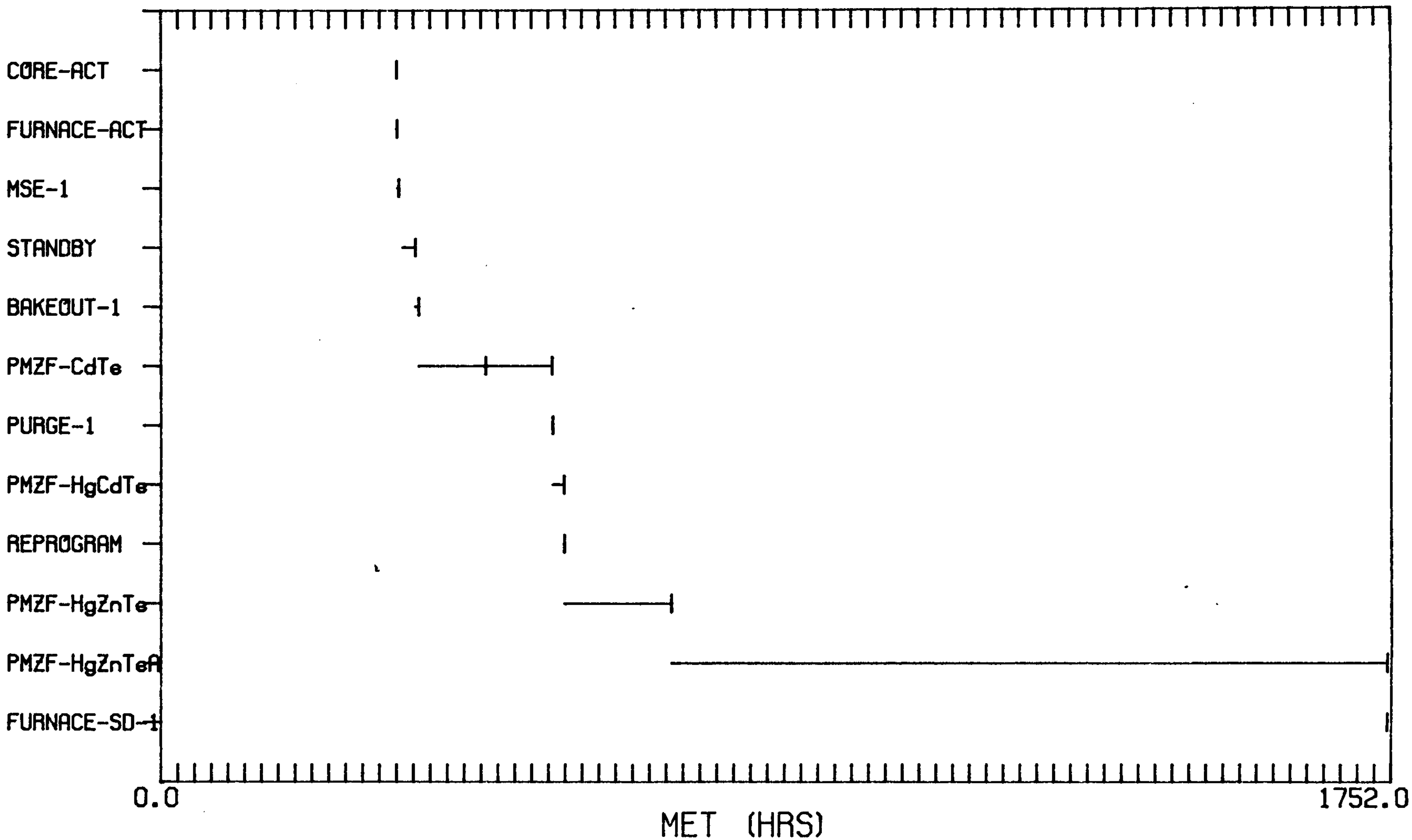
Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Until the time when resources are allocated for processing, the SSFF will remain in a standby mode. When resources are secured, samples may be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of the system and correct any problems.

A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples of CdTe occur next. Upon completion of processing a single sample the carousel within the furnace module will deliver a subsequent sample to be processed. Purging of both

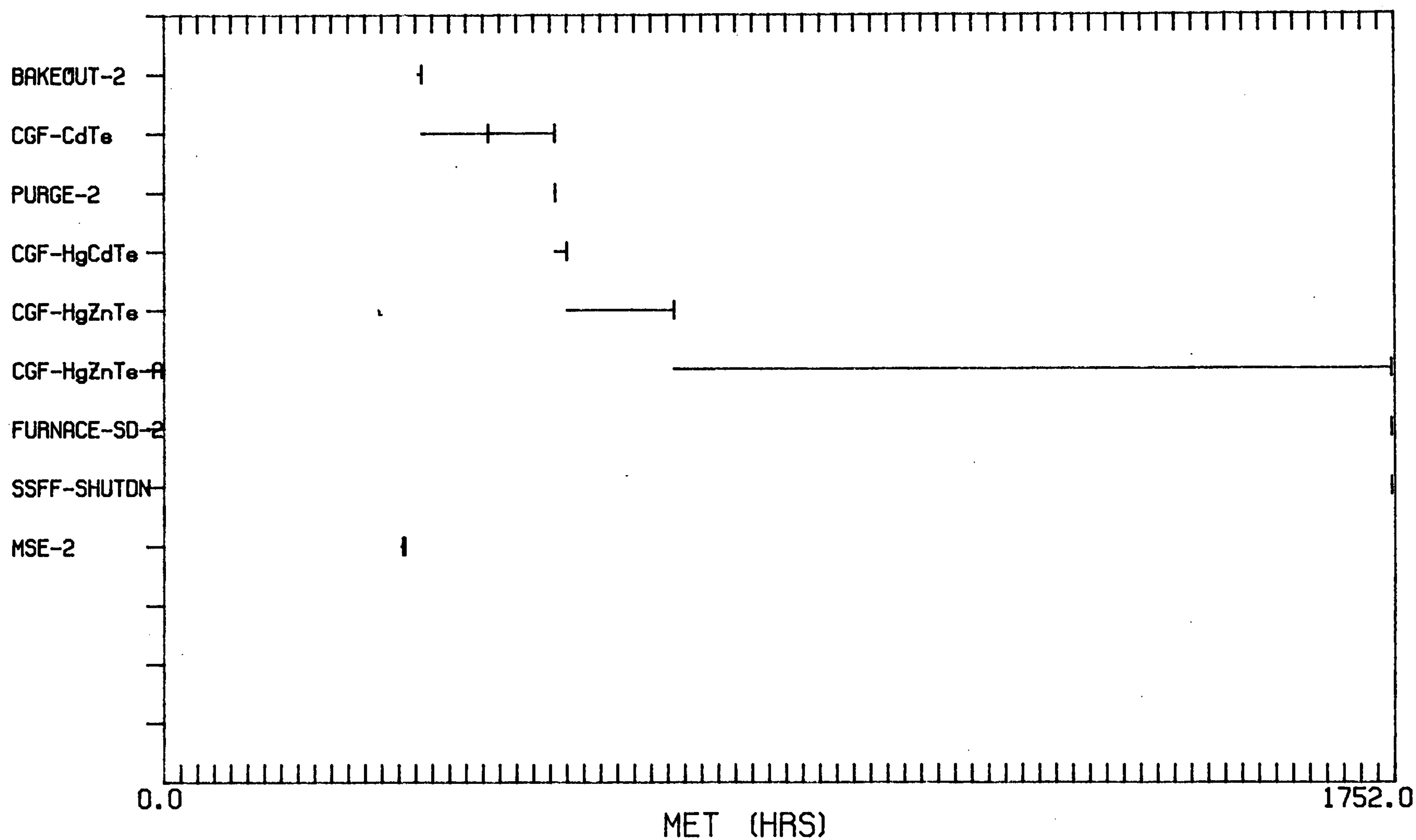
furnace modules occurs after the first three samples in the scenario described. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). A sample of HgCdTe, HgZnTe and an extended sample of HgZnTe are processed within the furnace modules. After HgCdTe a parameter change is initiated from the DMS. The Furnace Facility remains in a standby mode while this occurs. The delay for a reprogramming task is dependent on the ability to uplink information. In modeling this scenario reprogramming time was assumed to take approximately 20 minutes. Upon completion of the entire carousel of samples the Furnace Modules are returned to a standby mode.

From the standby mode complete shutdown can occur, however with crew available samples may be exchanged. The samples used in this scenario do not allow enough time for another carousel to be processed. Both furnaces will process one carousel apiece within a 90 day mission. Shutdown begins for the each furnace module after the completed carousel. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration requires the SSFF to vent processing gas from the furnace module, configure the TCS into the core rack, and place the furnace into the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

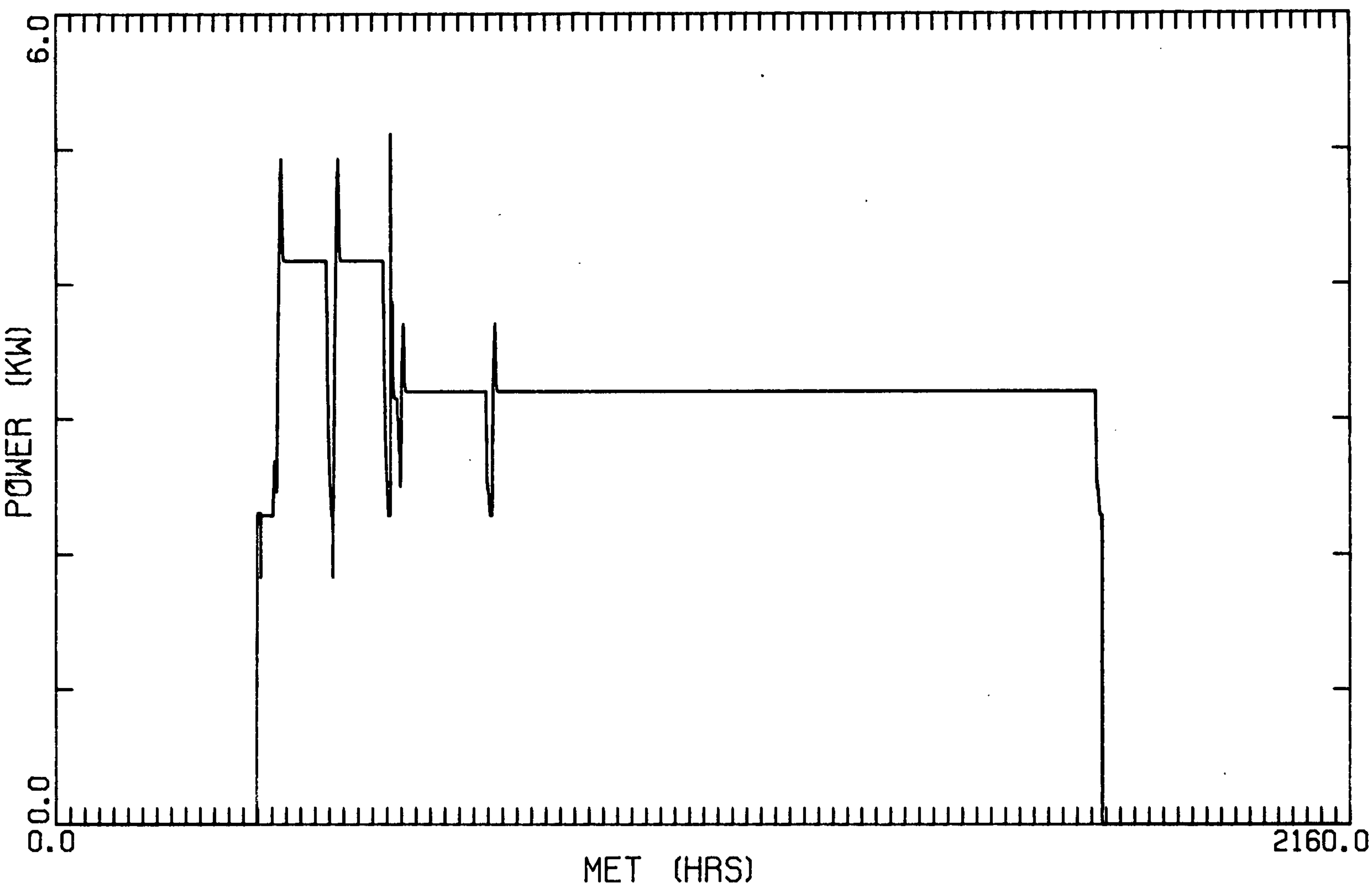
PMC REPRØGRAM TASK



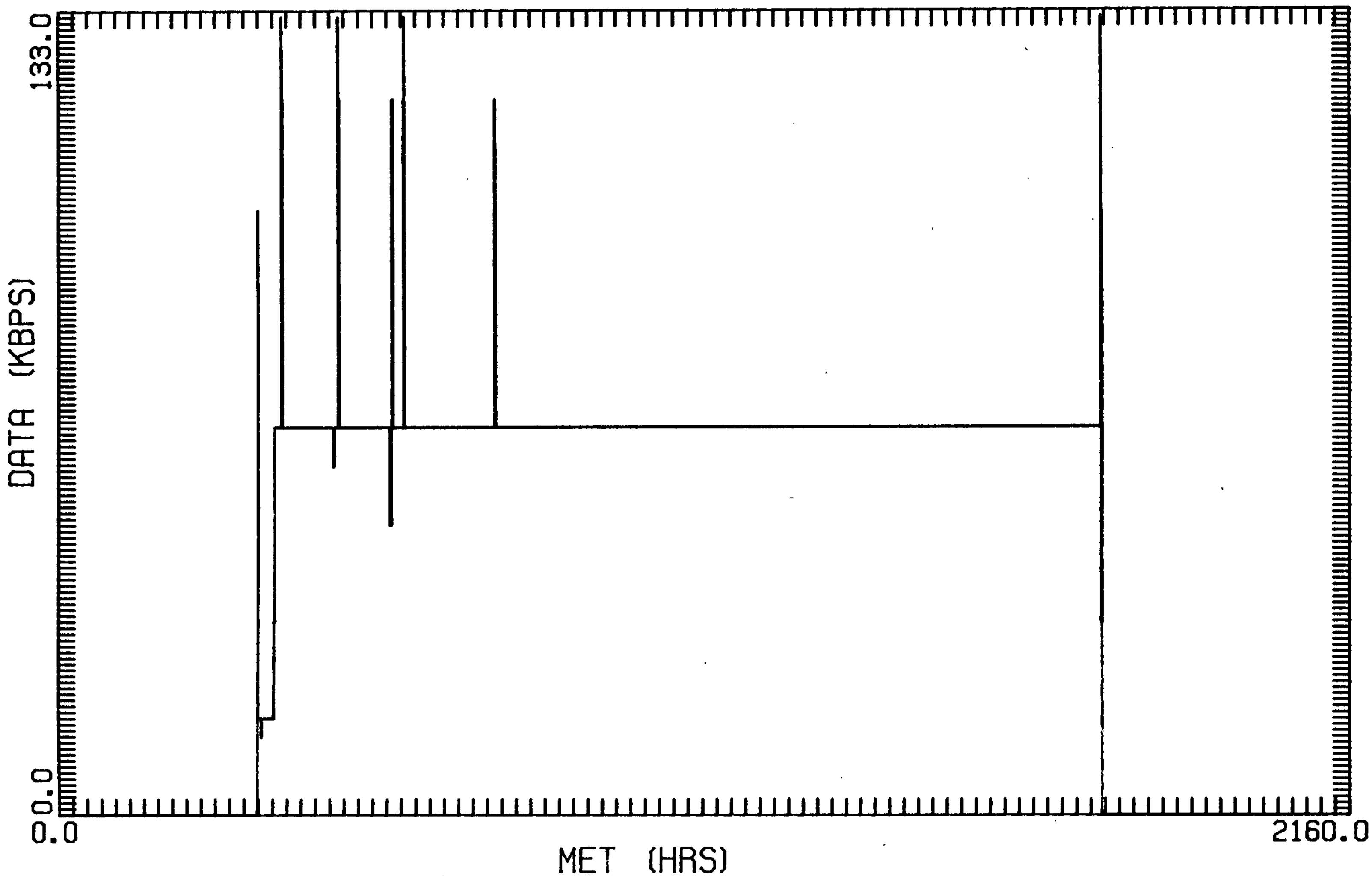
PMC REPRØGRAM TASK



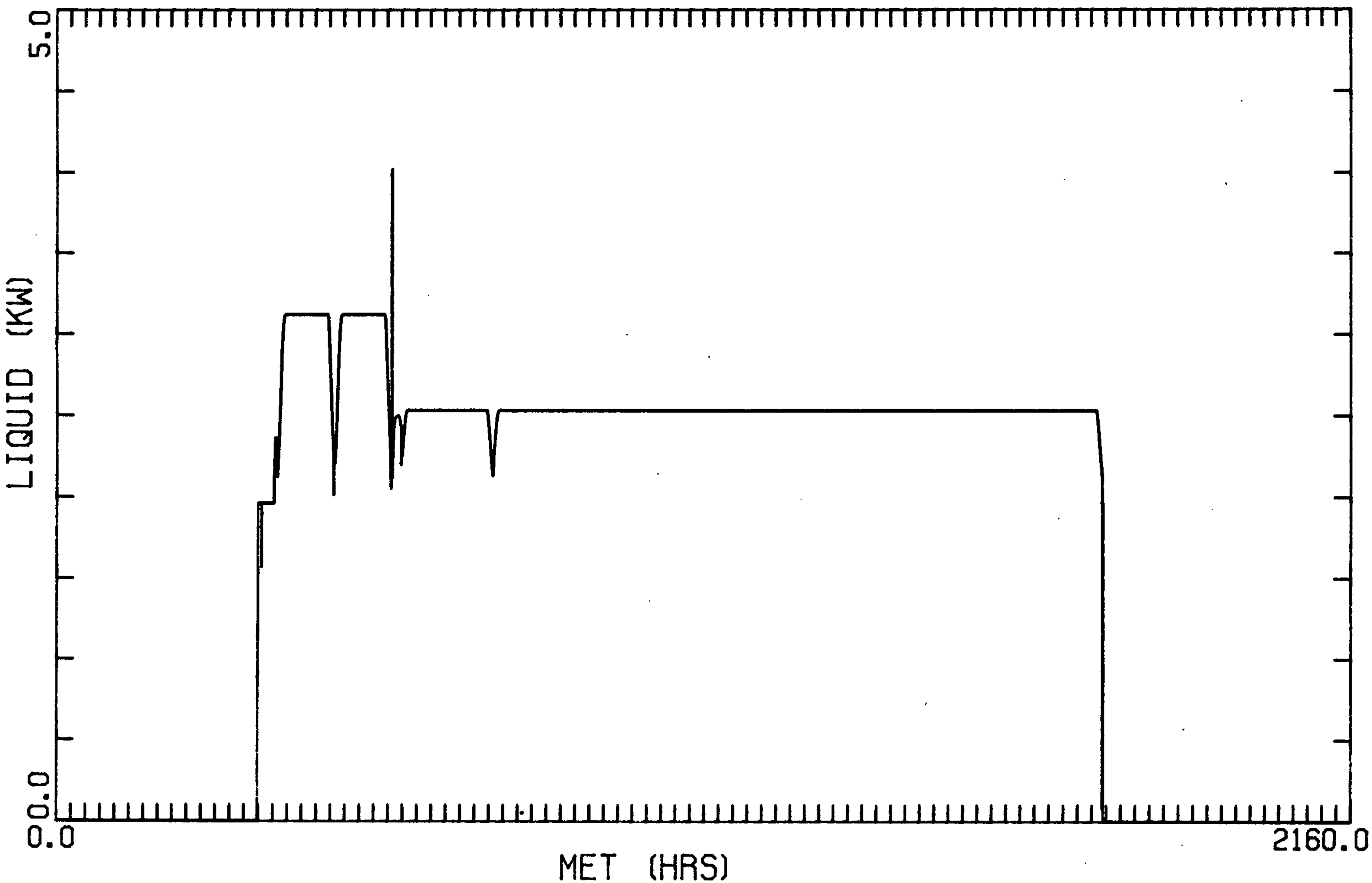
PMC REPRØGRAM TASK



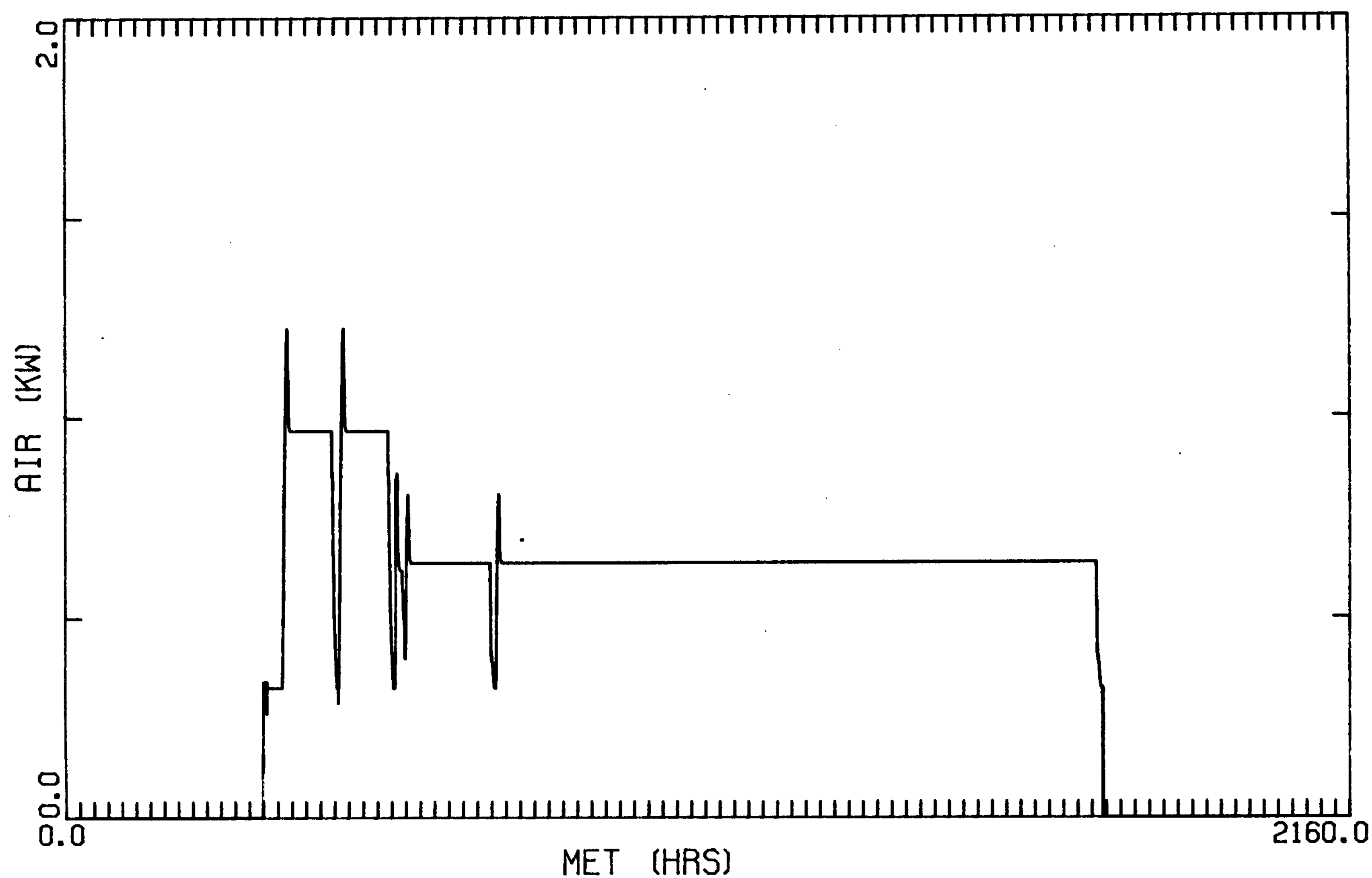
PMC REPRØGRAM TASK



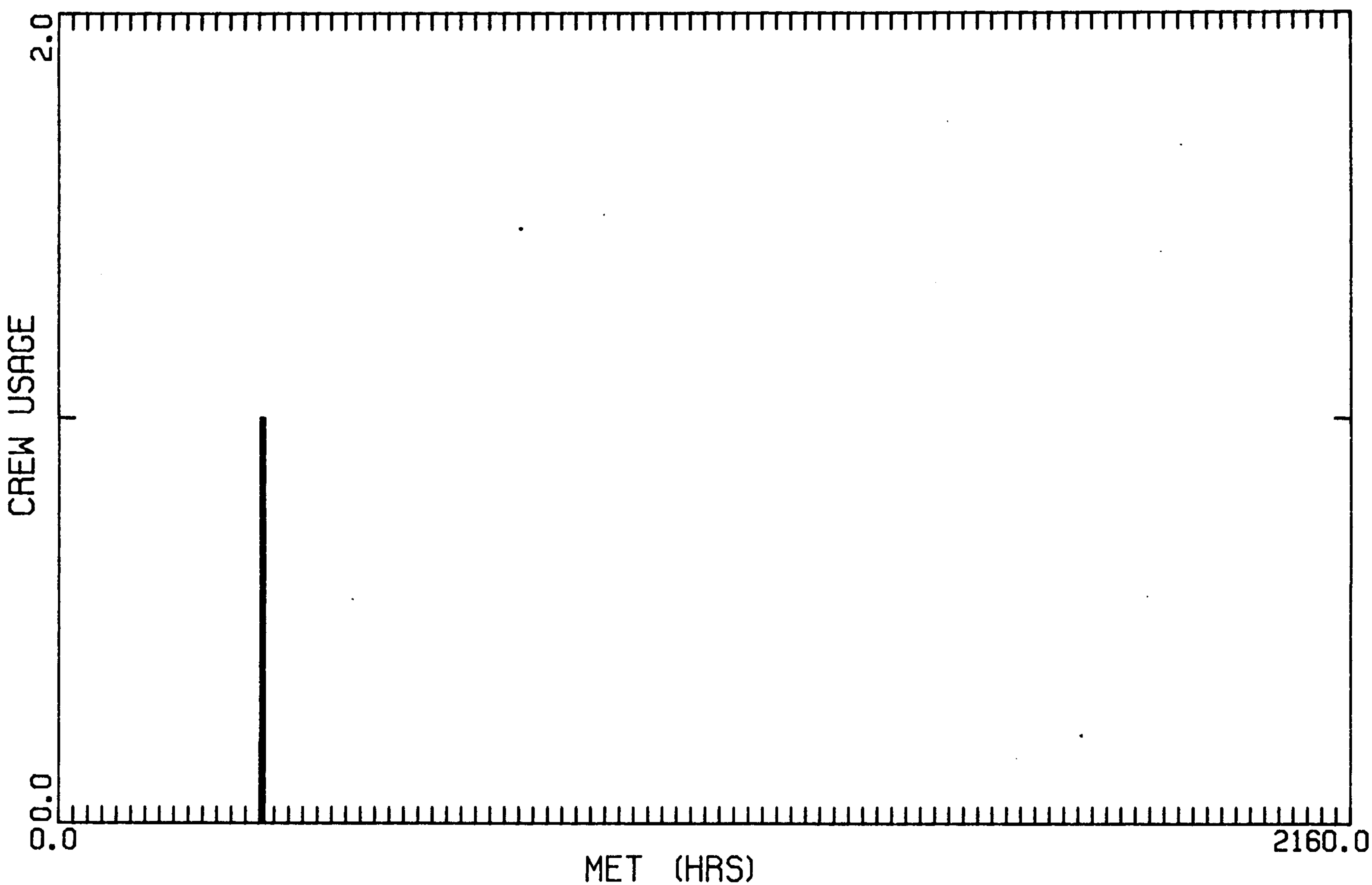
PMC REPRØGRAM TASK



PMC REPRØGRAM TASK



PMC REPRØGRAM TASK



PMC REPROGRAM TASK

MODEL CORE-ACT	INSERTED FROM	336.00	HRS TO	336.50	HRS
MODEL FURNACE-ACT	INSERTED FROM	336.50	HRS TO	336.95	HRS
MODEL MSE-1	INSERTED FROM	336.95	HRS TO	339.55	HRS
MODEL MSE-2	INSERTED FROM	339.55	HRS TO	342.15	HRS
MODEL STANDBY	INSERTED FROM	344.77	HRS TO	362.62	HRS
MODEL BAKEOUT-1	INSERTED FROM	362.62	HRS TO	367.62	HRS
MODEL PMZF-CdTe	INSERTED FROM	367.62	HRS TO	462.52	HRS
MODEL PMZF-CdTe	INSERTED FROM	462.53	HRS TO	557.43	HRS
MODEL PURGE-1	INSERTED FROM	557.43	HRS TO	558.20	HRS
MODEL PMZF-HgCdTe	INSERTED FROM	558.20	HRS TO	574.70	HRS
MODEL REPROGRAM	INSERTED FROM	574.70	HRS TO	575.03	HRS
MODEL PMZF-HgZnTe	INSERTED FROM	575.03	HRS TO	727.73	HRS
MODEL PMZF-HgZnTeA	INSERTED FROM	727.73	HRS TO	1746.32	HRS
MODEL FURNACE-SD-1	INSERTED FROM	1746.32	HRS TO	1746.47	HRS
MODEL BAKEOUT-2	INSERTED FROM	364.00	HRS TO	369.00	HRS
MODEL CGF-CdTe	INSERTED FROM	369.00	HRS TO	463.90	HRS
MODEL CGF-CdTe	INSERTED FROM	463.92	HRS TO	558.82	HRS
MODEL PURGE-2	INSERTED FROM	558.82	HRS TO	559.58	HRS
MODEL CGF-HgCdTe	INSERTED FROM	559.58	HRS TO	576.08	HRS
MODEL CGF-HgZnTe	INSERTED FROM	576.08	HRS TO	728.79	HRS
MODEL CGF-HgZnTe-A	INSERTED FROM	728.79	HRS TO	1747.39	HRS
MODEL FURNACE-SD-2	INSERTED FROM	1747.39	HRS TO	1747.54	HRS
MODEL SSFF-SHUTDN	INSERTED FROM	1747.54	HRS TO	1747.77	HRS

**** MAXIMUM RES1-POWER 5.131 KW
**** MAXIMUM RES2-DATA GENERATION 132.000 KBPS

**** TOTAL ENERGY RES1= 4626.42 KWH
**** TOTAL ENERGY RES2= 89052.43 KBPSH = 40073594 KBytes DATA VOLUME

GROUP 1 ENERGY RES1 =	4617.50 RES2 =	88969.23 CREW TIME (M-Hr) =	2.07
GROUP 2 ENERGY RES1 =	11.90 RES2 =	83.20 CREW TIME (M-Hr) =	4.13
GROUP 3 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 4 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 5 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 6 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 7 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 8 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 9 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 10 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 11 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 12 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 13 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 14 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 15 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 16 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 17 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 18 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 19 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00
GROUP 20 ENERGY RES1 =	0.00 RES2 =	0.00 CREW TIME (M-Hr) =	0.00

MAXIMUM NUMBER OF CREW = 1.000

AVG POWER SSFF = 3.277

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE-1	1	1	100.00000000%
MSE-2	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT-1	1	1	100.00000000%
PMZF-CdTe	2	2	100.00000000%
PURGE-1	1	1	100.00000000%
PMZF-HgCdTe	1	1	100.00000000%
REPROGRAM	1	1	100.00000000%
PMZF-HgZnTe	1	1	100.00000000%
PMZF-HgZnTeA	1	1	100.00000000%
FURNACE-SD-1	1	1	100.00000000%
BAKEOUT-2	1	1	100.00000000%
CGF-CdTe	2	2	100.00000000%
PURGE-2	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
FURNACE-SD-2	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

PMC REPROGRAM TASK

```
**** MAXIMUM RES1-LIQUID     4.027 KW
**** MAXIMUM RES2-AIR        1.225 KW


**** TOTAL ENERGY RES1=    3637.92 KWH
**** TOTAL ENERGY RES2=     933.58 KWH
GROUP  1 ENERGY RES1 =   3626.69 RES2 =     931.81 CREW TIME (M-Hr) =      0.00
GROUP  2 ENERGY RES1 =     10.20 RES2 =       1.71 CREW TIME (M-Hr) =      0.00
GROUP  3 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  4 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  5 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  6 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  7 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  8 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  9 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 10 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 11 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 12 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 13 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 14 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 15 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 16 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 17 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 18 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 19 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 20 ENERGY RES1 =      0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
```

PMC EXTENDED REPROGRAMMING TASK SCENARIO DESCRIPTION

Scenario #15 displays a short delay in processing for Furnace Module #1 and an extended delay in processing for Furnace Module #2. The reprogramming task occurs after completion of the forth sample in Furnace Module #1. The extended reprogramming task occurs after completion of the first sample in Furnace Module #2. The SSFF remains in standby during delays for reprogramming of the processing parameters. This reflects a scenario in reprogramming run specific data for both furnaces. The extended delay is due to constraints in the ability to uplink new software. The type of samples processed are the same as in Scenario #9.

PMC EXTENDED REPROGRAMMING TASK SCENARIO OVERVIEW

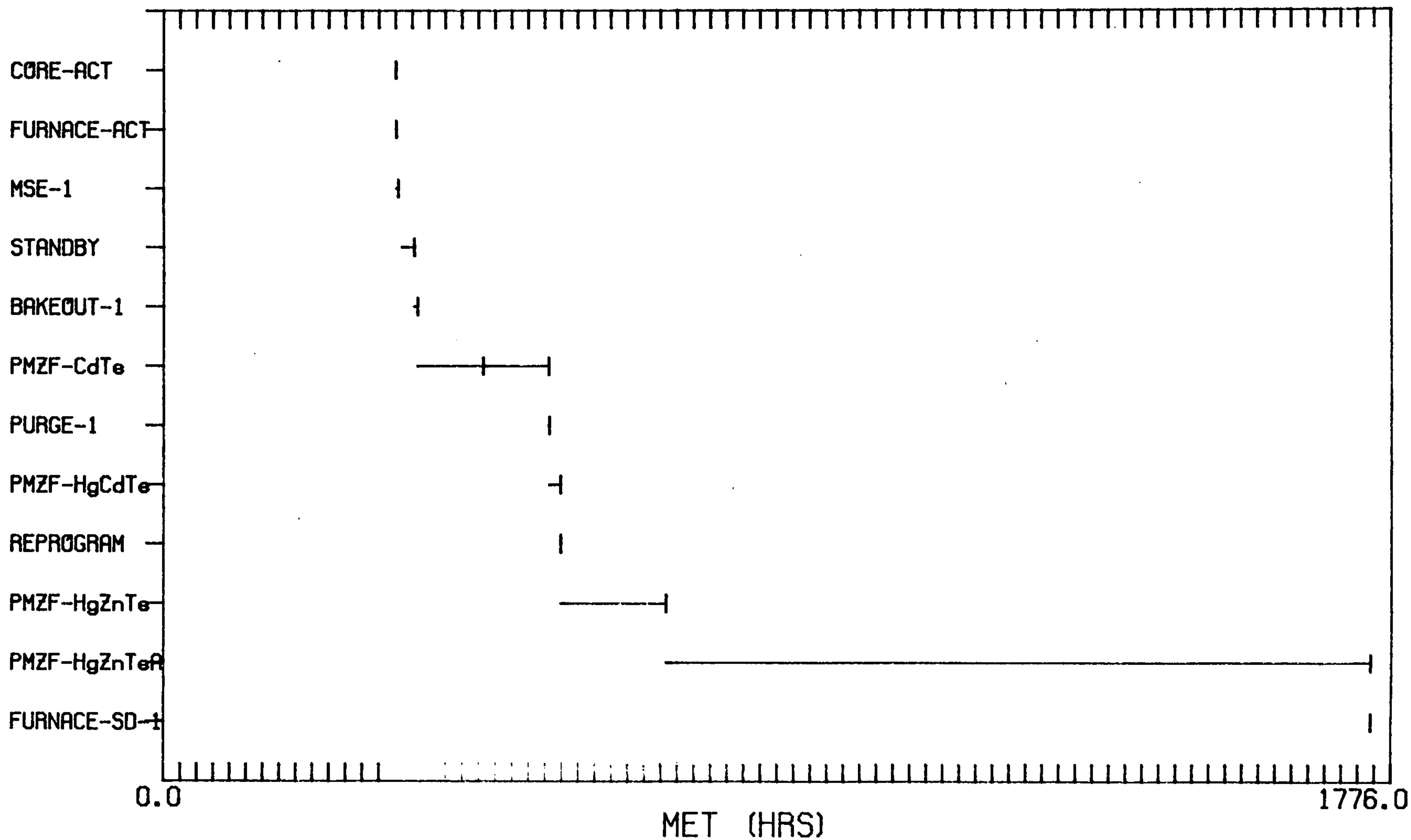
The operation of the SSFF in this scenario is as follows: Installation of Furnace Module #2 occurs on Utilization Flight TBD. As in MTC configuration, the checkout of all hoses, lines, and equipment will be performed by the crew during installation of the second furnace module. Upon completion of the installation, activation of the SSFF will occur. Activation occurs in the order of the core equipment, the distributed equipment for Furnace Module#1, and the distributed equipment for Furnace Module #2. Core Activation consists of applying power and checkout of all equipment in the Core rack. Distributed Equipment Activation consists of applying power and checkout of all equipment located within each furnace rack. The Furnace Modules are included in this activation step. After all equipment is powered and warm-up, the SSFF reaches a standby mode. This Standby mode is where power consumption for subsystems are at normal operating amounts and both Furnace Module power consumption is at zero. The SSFF will fall back to these levels at several times during normal operation in the 90 day mission. Samples may now be loaded by the crew.

Samples are loaded while the SSFF is in a Manual Sample Exchange stage. This stage allows the SSFF subsystems to remain in standby while the furnace modules are in a safe condition for crew interaction. After the samples are loaded in Furnace Module #1, it is purged with nitrogen. The Furnace Module is then prepared for processing of samples by venting of the nitrogen and filling with a processing gas. Argon is the processing gas in this scenario. At this time Furnace Module #2 can be loaded with samples. The procedure is identical to that of Furnace Module #1. Processing will occur for Furnace Module #1 and for Furnace Module #2 when the required resources are secured from SSF. Until the time when resources are allocated for processing, the SSFF will remain in a standby mode. When resources are secured, samples may be processed simultaneously in both Furnace Modules. Crew will be available throughout PMC configuration to check for proper operation of the system and correct any problems.

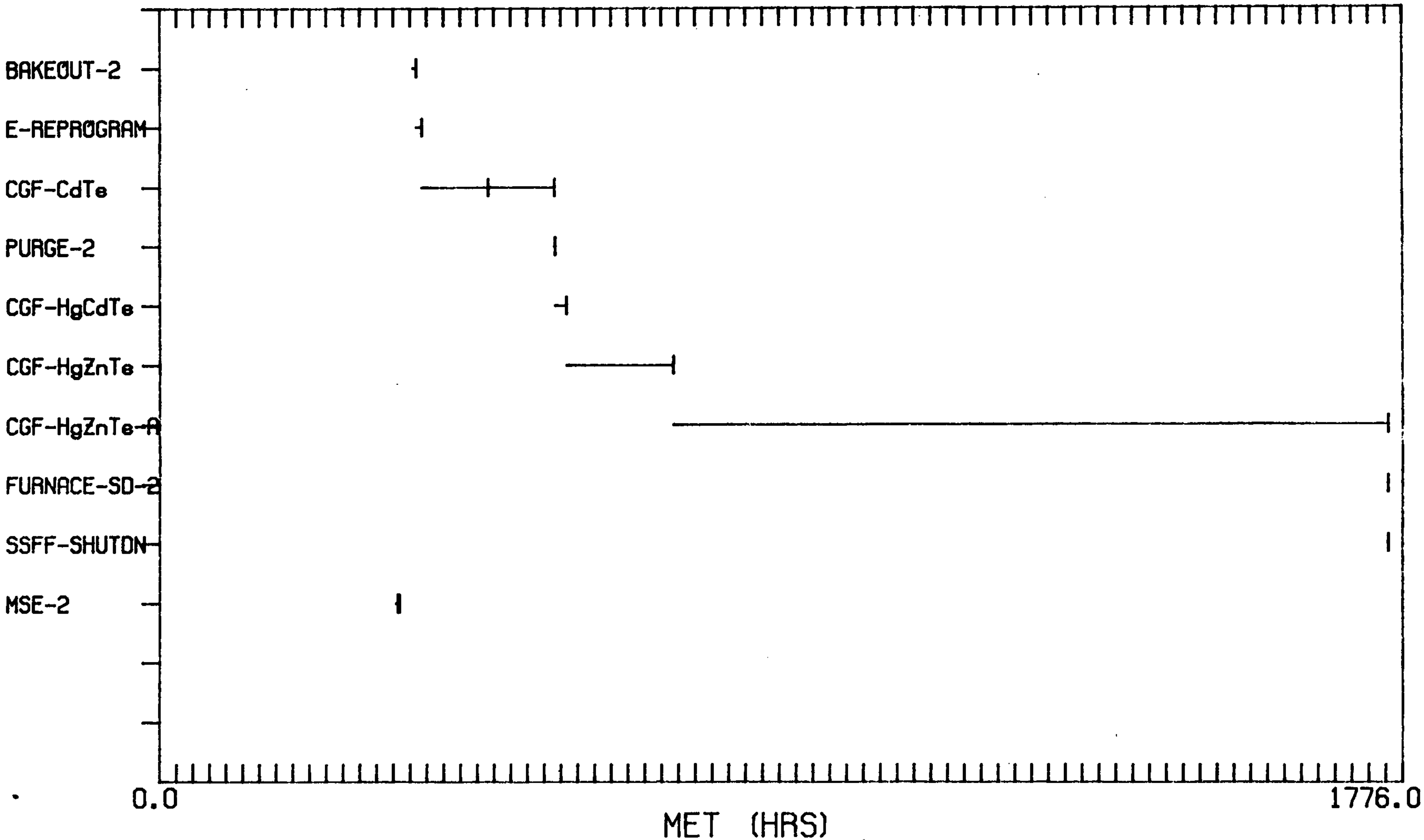
A signal from the Core Control Unit (CCU) will allow for the furnaces to power up and start the processing cycle. The processing samples are duplicated in both Furnace Modules. The first sample to be processed is a calibration and bakeout sample. This calibrates the furnaces at a predetermined time limit and proceeds with a bakeout of approximately 5 hours. Processing of two samples of CdTe occur next. Upon completion of processing a single sample the carousel within the furnace module will deliver a subsequent sample to be processed. Purging of both furnace modules occurs after the first three samples in the scenario described. Depending on the degradation of ampoules, the amount of purges between samples can be increased (the increase in purges are consistent with the operation of the SSFF, however purges are limited by the resources available). A sample of HgCdTe, HgZnTe and an extended sample of HgZnTe are processed within the furnace modules. In Furnace Module #2 a parameter change is initiated by the DMS. This Furnace Module remains in a standby mode while this occurs. The delay for a reprogramming task is dependent on the ability to uplink information. In modeling this scenario an extended reprogramming time was assumed to take approximately 8 hours. This delay reflects possible constraints in uplinking software. After reprogramming of Furnace Module #2 is completed, the remaining samples are processed in this module. In Furnace Module #1, a parameter change is initiated from the DMS after HgCdTe. The Furnace Facility remains in a standby mode while this occurs. In modeling this scenario reprogramming time for this module was assumed to take approximately 20 minutes. After reprogramming of this module the remaining samples are processed. Upon completion of the entire carousel of samples the Furnace Modules are returned to a standby mode.

From the standby mode complete shutdown can occur, however with crew available samples may be exchanged. The samples used in this scenario do not allow enough time for another carousel to be processed. Both furnaces will process one carousel apiece within a 90 day mission. Shutdown begins for the each furnace module after the completed carousel. Shutdown occurs through a process of: reconfiguration of SSFF, distributed equipment deactivation and deactivation of core equipment. Reconfiguration requires the SSFF to vent processing gas from the furnace module, configure the TCS into the core rack, and place the furnace into the home position. Deactivation of the Distributed equipment occurs followed by deactivation of the core equipment. Upon notification from SSFF to suspend resources from SSF, the Furnace Facility is completely shutdown.

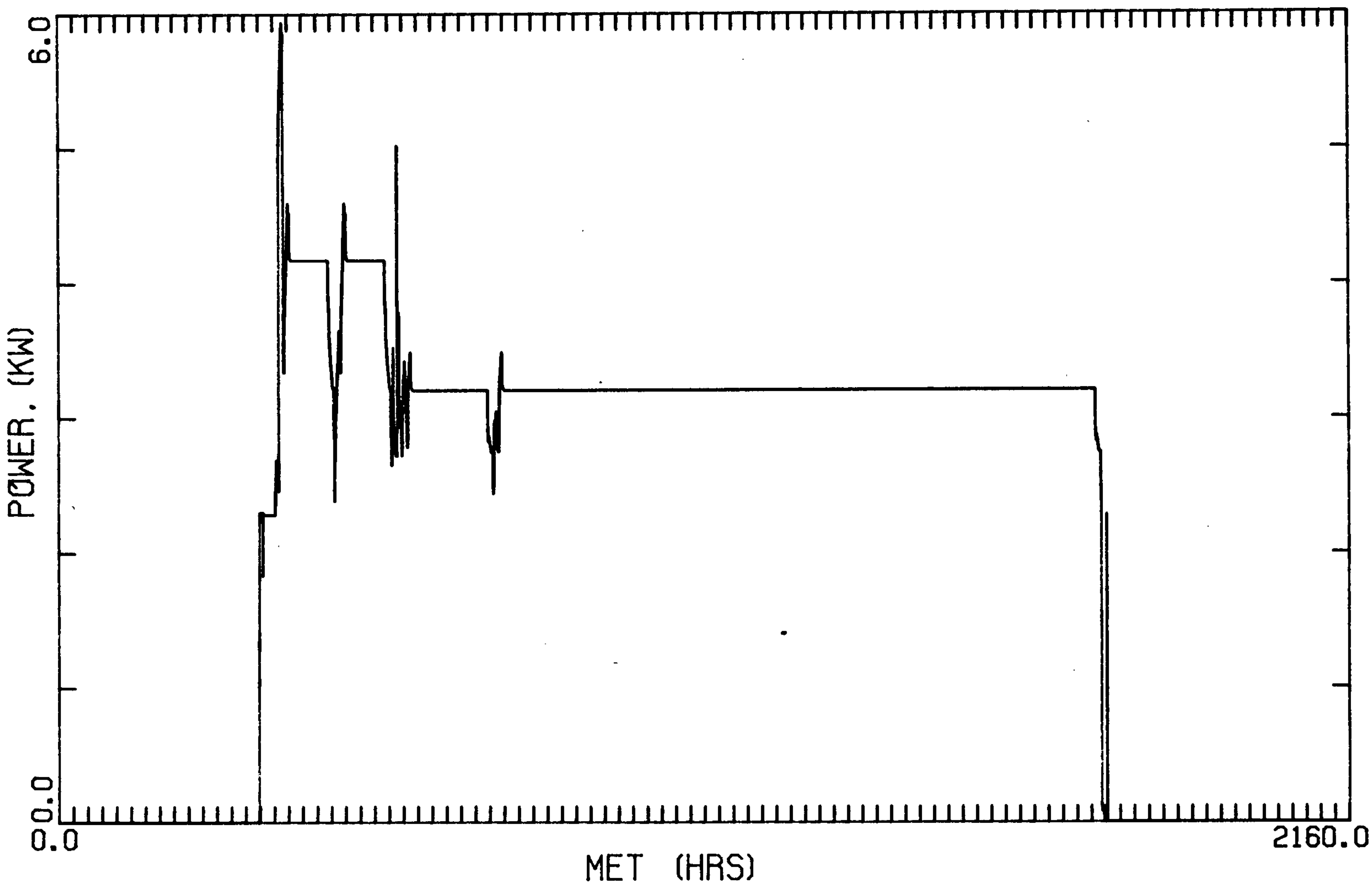
PMC REPROGRAM DELAY



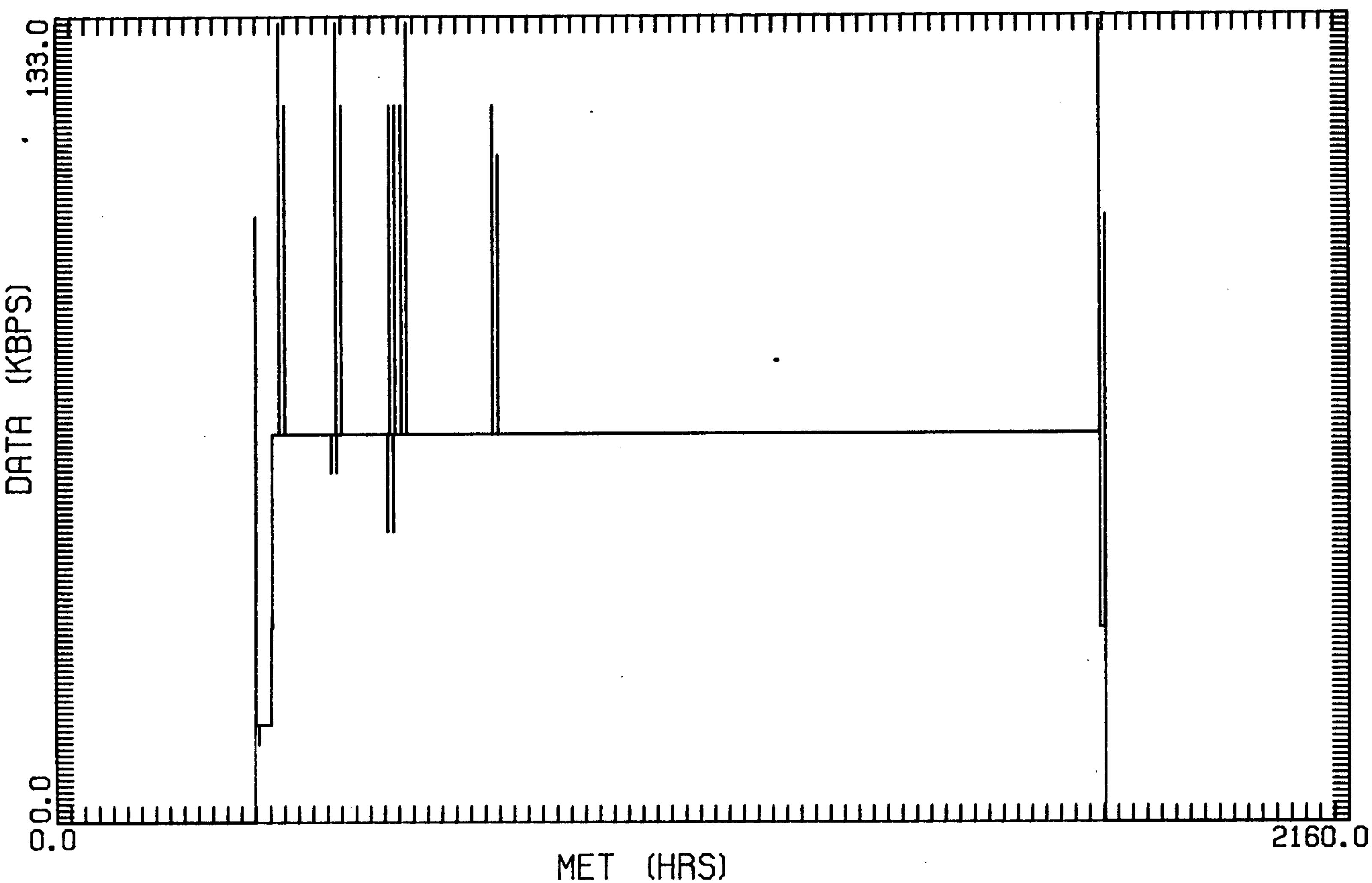
PMC REPRØGRAM DELAY

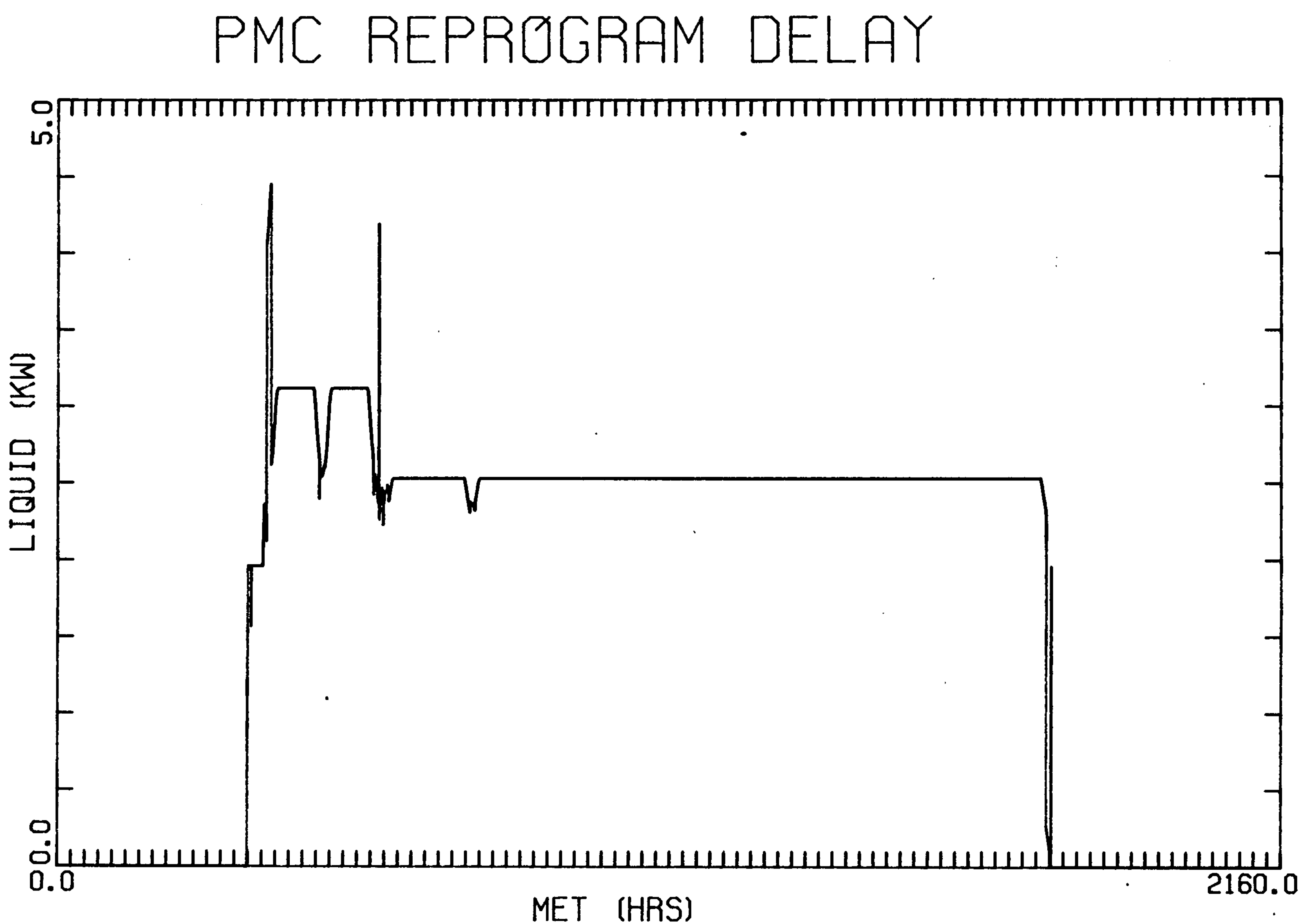


PMC REPRØGRAM DELAY



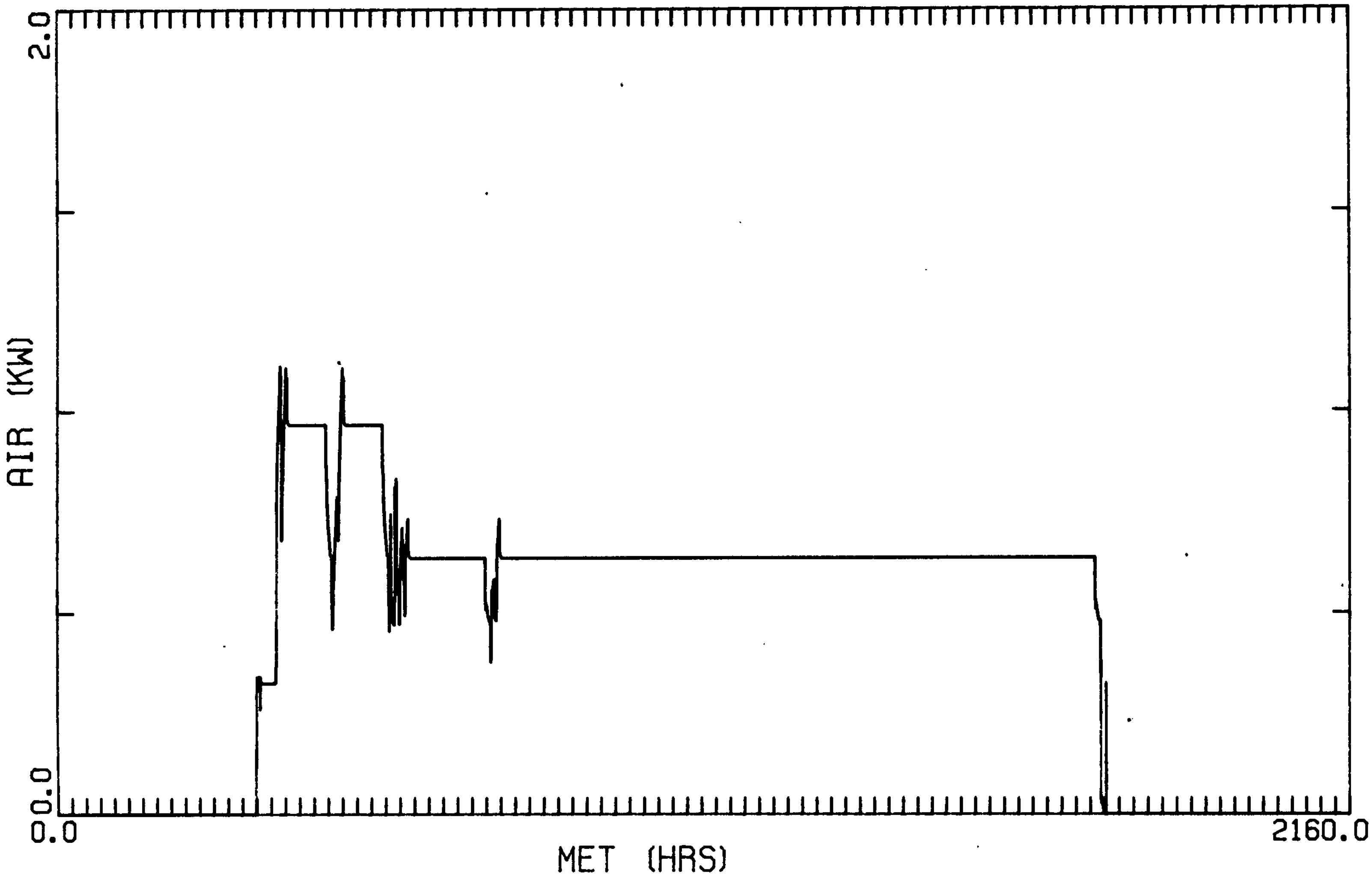
PMC REPRØGRAM DELAY





PMC REPRØGRAM DELAY
5.0
LIQUID (KW)
0.0
0.0
2160.0
MET (HRS)

PMC REPRØGRAM DELAY



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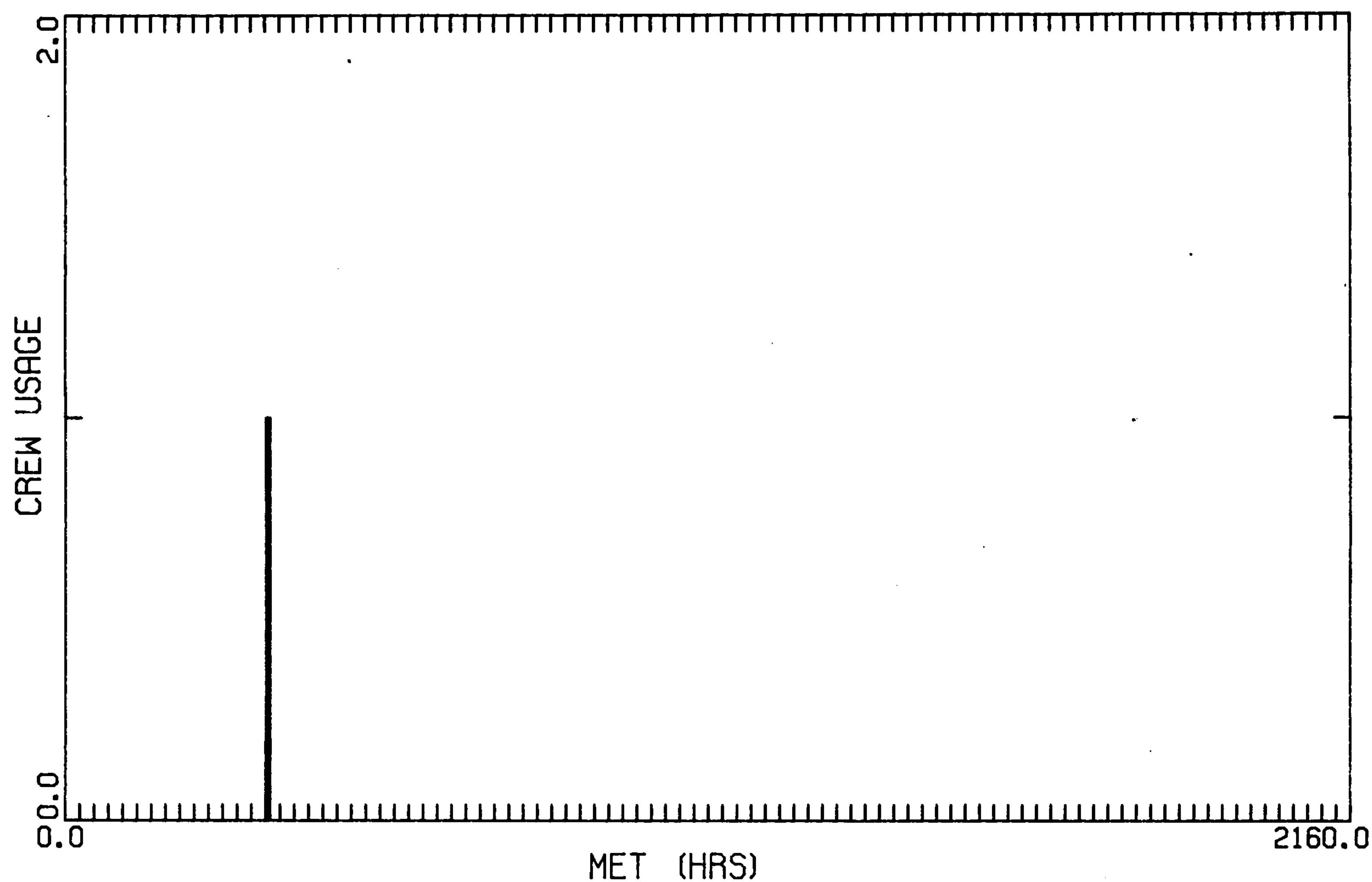


PMC REPROGRAM DELAY

```
MODEL CORE-ACT      INSERTED FROM    336.00 HRS TO    336.50 HRS
MODEL FURNACE-ACT   INSERTED FROM    336.50 HRS TO    336.95 HRS
MODEL MSE-1         INSERTED FROM    336.95 HRS TO    339.55 HRS
MODEL MSE-2         INSERTED FROM    339.55 HRS TO    342.15 HRS
MODEL STANDBY       INSERTED FROM    344.77 HRS TO    362.62 HRS
MODEL BAKEOUT-1     INSERTED FROM    362.62 HRS TO    367.62 HRS
MODEL PMZF-CdTe     INSERTED FROM    367.62 HRS TO    462.52 HRS
MODEL PMZF-CdTe     INSERTED FROM    462.53 HRS TO    557.43 HRS
MODEL PURGE-1       INSERTED FROM    557.43 HRS TO    558.20 HRS
MODEL PMZF-HgCdTe   INSERTED FROM    558.20 HRS TO    574.70 HRS
MODEL REPROGRAM     INSERTED FROM    574.70 HRS TO    575.03 HRS
MODEL PMZF-HgZnTe   INSERTED FROM    575.03 HRS TO    727.73 HRS
MODEL PMZF-HgZnTeA  INSERTED FROM    727.73 HRS TO   1746.32 HRS
MODEL FURNACE-SD-1  INSERTED FROM   1746.32 HRS TO   1746.47 HRS
MODEL BAKEOUT-2     INSERTED FROM    364.00 HRS TO    369.00 HRS
MODEL E-REPROGRAM   INSERTED FROM    369.00 HRS TO    377.00 HRS
MODEL CGF-CdTe      INSERTED FROM    377.00 HRS TO    471.90 HRS
MODEL CGF-CdTe      INSERTED FROM    471.92 HRS TO    566.82 HRS
MODEL PURGE-2       INSERTED FROM    566.82 HRS TO    567.58 HRS
MODEL CGF-HgCdTe    INSERTED FROM    567.58 HRS TO    584.08 HRS
MODEL CGF-HgZnTe    INSERTED FROM    584.08 HRS TO    736.79 HRS
MODEL CGF-HgZnTe-A  INSERTED FROM    736.79 HRS TO   1755.39 HRS
MODEL FURNACE-SD-2  INSERTED FROM   1755.39 HRS TO   1755.54 HRS
MODEL SSFF-SHUTDN   INSERTED FROM   1755.54 HRS TO   1755.77 HRS


**** MAXIMUM RES1-POWER    5.936 KW
**** MAXIMUM RES2-DATA GENERATION  132.000 KBPS


**** TOTAL ENERGY RES1=    4644.84 KWH
**** TOTAL ENERGY RES2=   89308.43 KBPSH = 40188794 KBytes DATA VOLUME
GROUP  1 ENERGY RES1 =    4636.38 RES2 =   89225.23 CREW TIME (M-Hr) =      2.07
GROUP  2 ENERGY RES1 =      11.90 RES2 =      83.20 CREW TIME (M-Hr) =      4.13
GROUP  3 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  4 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  5 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  6 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  7 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  8 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP  9 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 10 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 11 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 12 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 13 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 14 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 15 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 16 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 17 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 18 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 19 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00
GROUP 20 ENERGY RES1 =       0.00 RES2 =       0.00 CREW TIME (M-Hr) =      0.00


MAXIMUM NUMBER OF CREW =     1.000
```

AVG POWER SSFF = 3.2715 KW

EXPERIMENTS	NO.RUNS	DESIRED RUNS	PERCENTAGE
CORE-ACT	1	1	100.00000000%
FURNACE-ACT	1	1	100.00000000%
MSE-1	1	1	100.00000000%
MSE-2	1	1	100.00000000%
STANDBY	1	1	100.00000000%
BAKEOUT-1	1	1	100.00000000%
PMZF-CdTe	2	2	100.00000000%
PURGE-1	1	1	100.00000000%
PMZF-HgCdTe	1	1	100.00000000%
REPROGRAM	1	1	100.00000000%
PMZF-HgZnTe	1	1	100.00000000%
PMZF-HgZnTeA	1	1	100.00000000%
FURNACE-SD-1	1	1	100.00000000%
BAKEOUT-2	1	1	100.00000000%
E-REPROGRAM	1	1	100.00000000%
CGF-CdTe	2	2	100.00000000%
PURGE-2	1	1	100.00000000%
CGF-HgCdTe	1	1	100.00000000%
CGF-HgZnTe	1	1	100.00000000%
CGF-HgZnTe-A	1	1	100.00000000%
FURNACE-SD-2	1	1	100.00000000%
SSFF-SHUTDN	1	1	100.00000000%

PMC REPROGRAM DELAY

**** MAXIMUM RES1-LIQUID 4.451 KW
**** MAXIMUM RES2-AIR 1.113 KW

**** TOTAL ENERGY RES1= 3653.61 KWH
**** TOTAL ENERGY RES2= 936.17 KWH

GROUP 1	ENERGY RES1 =	3642.44	RES2 =	934.41	CREW TIME	(M-Hr)	=	0.00
GROUP 2	ENERGY RES1 =	10.20	RES2 =	1.71	CREW TIME	(M-Hr)	=	0.00
GROUP 3	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 4	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 5	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 6	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 7	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 8	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 9	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 10	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 11	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 12	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 13	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 14	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 15	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 16	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 17	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 18	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 19	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00
GROUP 20	ENERGY RES1 =	0.00	RES2 =	0.00	CREW TIME	(M-Hr)	=	0.00

DR-2

Space Station Furnace Facility (SSFF)

Trade Study on

Furnace Orientation System

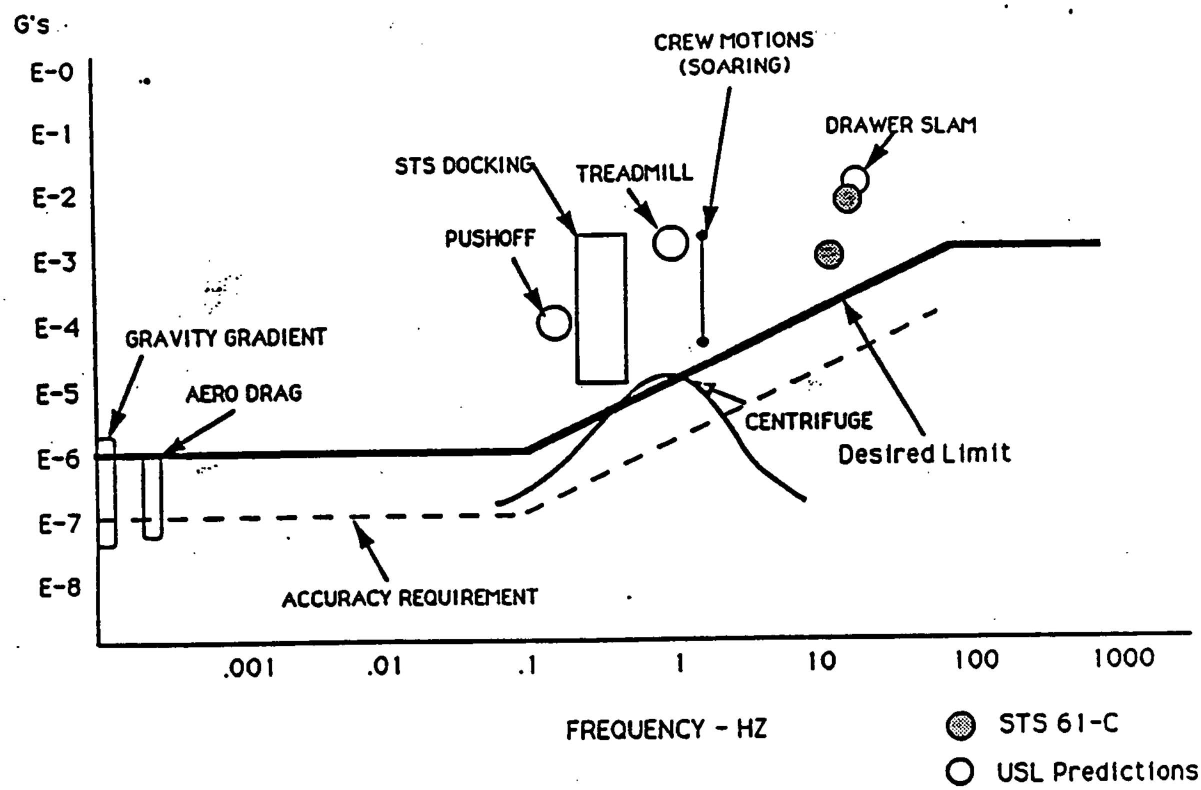
Conceptual Design Review
August 20-21, 1990
8:30 am - 4:30 pm
MSFC Building 4201
Room 437

INTRODUCTION

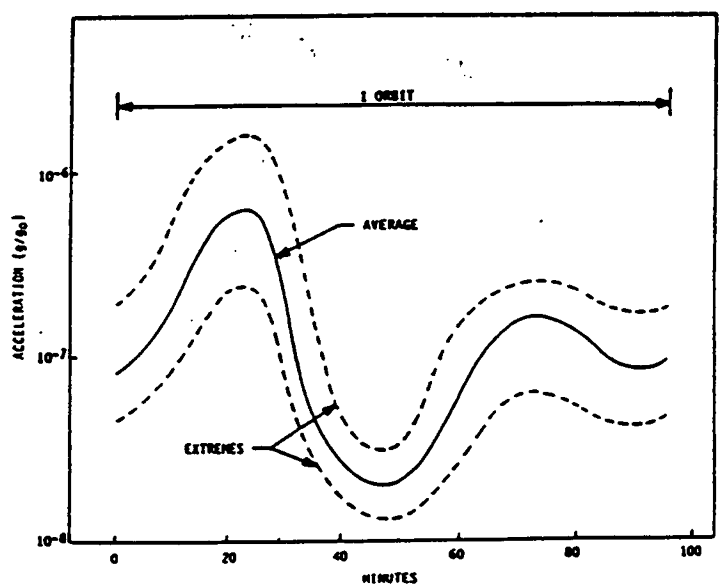
The purposes of this study are to determine the feasibility and develop a concept for a furnace pointing system. This system will be part of the Space Station Furnace Facility (SSFF).

This system will be used to align the furnace axis parallel to the residual gravity vector on the space station. The residual gravity vector is composed of the air drag component and the gravity-gradient component. Other acceleration inducing steady-state disturbances such as light pressure are considered to be several orders of magnitude less. The gravity-gradient force is produced by the radial variation in the force of gravity about the space station center of mass. An object will only experience a zero gravity gradient if it is positioned along the flight path of the space station's center of mass. The current configuration for the Space Station Freedom (SSF) will place the U.S. lab module approximately 12 m from the space station Center of Mass (CM). This displacement will impose an Earth-directed component of 3×10^{-6} g (~.1μg per meter) and a CM-directed component along the truss axis of 1×10^{-6} g on the furnace module (worst-case assumptions based on the current configuration). The magnitude and direction of the gravity-gradient components are considered to be constant in the study as the center of mass position of the space station will be considered to be unchanging.

The air drag force is produced by atmospheric drag at the orbital altitude. This component is cyclic in nature and varies at approximately two cycles per orbit. The magnitude of the air drag component varies significantly with atmospheric conditions and is a function of solar flux, diurnal bulge, orbital altitude, time of year, and projected area of the space station. A plot of the expected acceleration environment on the Space Station is shown in Figure 1. This study will consider two cases: where the air drag is of the same magnitude as the gravity gradient (maximum of 3×10^{-6} g) and where the maximum air drag is one order of magnitude less than the gravity gradient. The scenario in which both components are of the same order of magnitude represents a worst-case orientation (from the perspective of the rack space required by the system).



Space Station Expected Acceleration Environment



Deceleration of Space Station Caused by Atmospheric Drag

Figure 1

OBJECTIVE

The pointing system will be required to maintain a preferred alignment (based on the particular science requirements of the experiment) with the residual gravity vector. The benefits of both an active and passive alignment system will be weighted. This study must also determine any disturbances induced on the furnace module by the pointing system. The sense and magnitude of the gravity vector and the preferred orientation will be determined and controlled by an accelerometer subsystem. The system must be capable of accommodating a variety of furnace module shapes and allow on-orbit module interchangeability.

CONCEPTUAL DESIGN

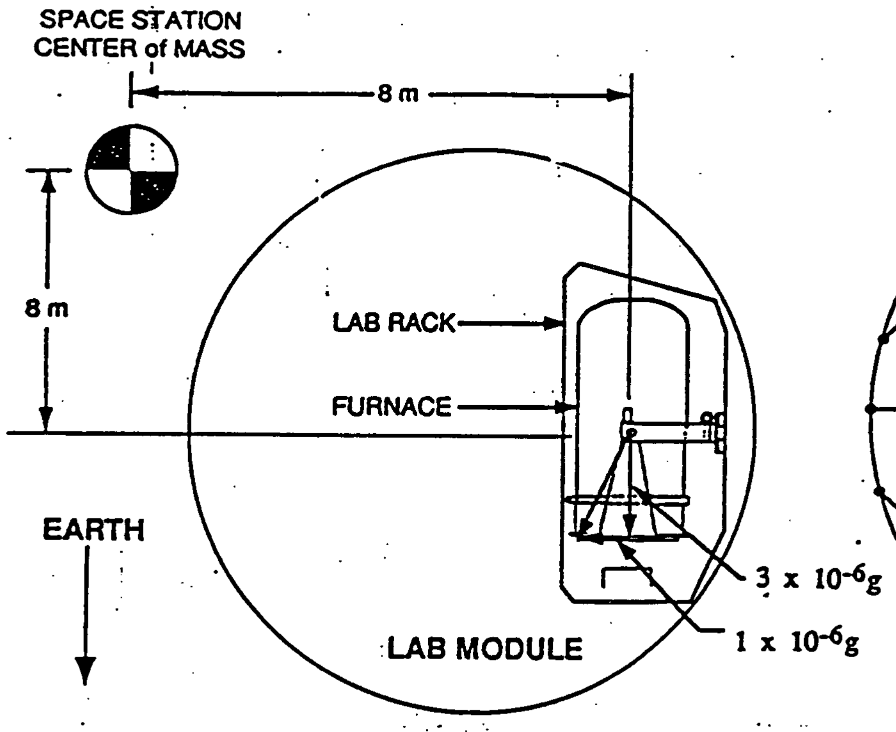
I. ROTATION LIMITS AND DISTURBANCES

The first step required by this study is the determination of the disturbances induced on the furnace module by the pointing system. Rotational induced disturbances are based on maximum normal acceleration of 10^{-6} g and a maximum tangential acceleration of 1.6 x 10^{-7}g. Furnace dimensions and mass are based on the Crystal Growth Furnace (CGF) design and assume tracking rotation about the furnace center of mass. A worst case radius from the center of rotation to the sample of 1.7 ft was used. The maximum allowable angular velocity (w_{max}) was calculated to be 4.4 x 10^{-3} rad/sec or 15 deg/min. The tangential velocity based on w_{max} was calculated to be 0.007 ft/sec with a minimum acceleration time to w_{max} of 24 minutes. Based on these numbers, the maximum angular acceleration (amax) is 3.0 x 10^{-6} rad/sec^2. Based on CGF, the torque induced by rotating the furnace at amax is 2.55 x 10^{-3} oz-in. The torque required to rotate the furnace at amax is unlikely to produce any disturbance in the US lab module. Other potential disturbance sources are:

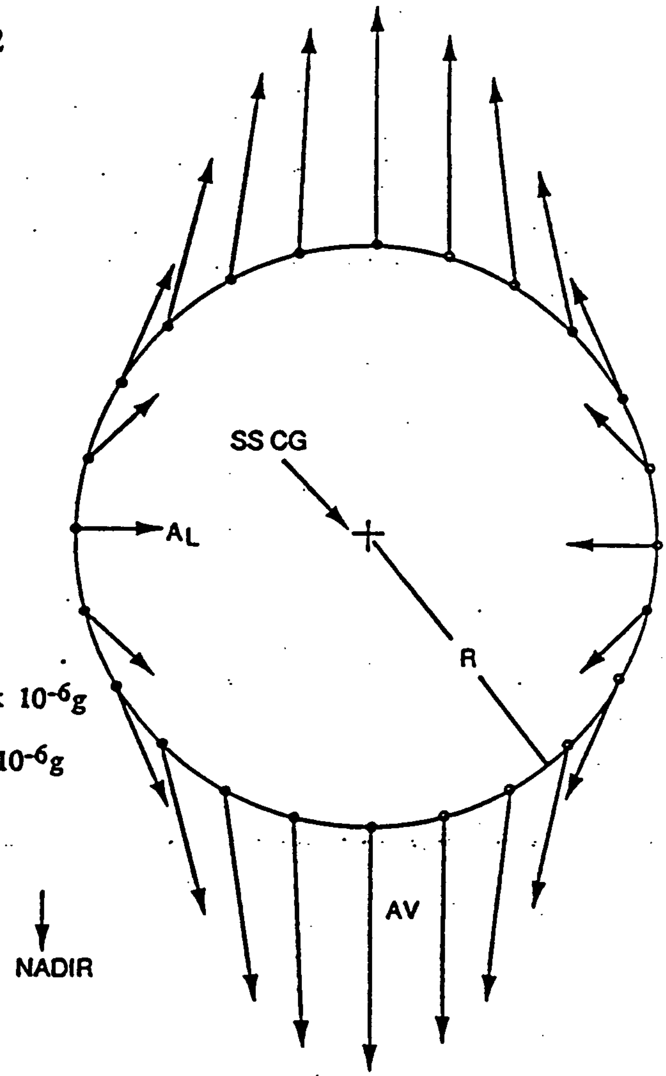
- Stiction in the rotation bearing system
- Drive train noise
- Connection hose binding and interaction.

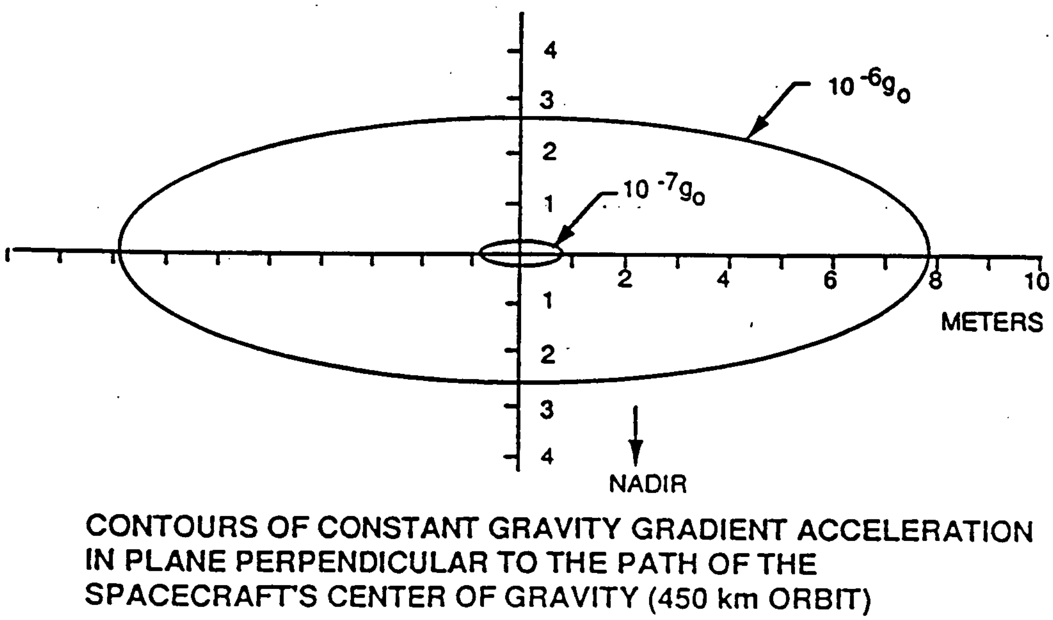
Calculations of the furnace position during the orbital period are based on a 10^{-3} Hz variation of air drag ranging in magnitude from 3 x10^{-6} g to 3 x 10^{-7} g. Based on the gravity-gradient contour plots and the furnace position shown in Figure 2, the gravity-gradient components were found to be 1.0 x 10^{-6} g along the truss axis and 3 x10^{-6} g in the Earth direction. These components produce a resultant of 3.16 x 10^{-6} g magnitude at a direction 18 deg off the Earth direction axis. The furnace module will need to be tilted at an 18-deg angle to maintain alignment with this component. The air drag component of 3 x 10^{-6} g requires a tilt angle of 44 deg from Earth direction for parallel alignment. An air drag component of 3 x 10^{-7} g requires a tilt angle of 5 deg from Earth direction. Based on these two angles, the furnace must rotate through a 39-deg angle, four times per orbit, or rotate through 39 deg during a 22-min period in a worst-case scenario.

FIGURE 2



TILT ANGLE $\emptyset = \tan^{-1}(1\times10^{-6}/3\times10^{-6}) = 18^{o}$
ASSUMING 3 X 10^{-6}G IS WORST CASE





CONTOURS OF CONSTANT GRAVITY GRADIENT ACCELERATION
IN PLANE PERPENDICULAR TO THE PATH OF THE
SPACECRAFT'S CENTER OF GRAVITY (450 km ORBIT)

Assuming the worst case, variation in air drag will be 3×10^{-6} g - (3×10^{-7} g) or 2.7×10^{-6} g; the average angular velocity will be 5.0×10^{-4} rad/sec. This is well below the calculated maximum of 4.4×10^{-3} rad/sec. The rotation about the furnace CG of 5.0×10^{-4} rad/sec will produce a normal acceleration component of 10^{-8}g.

This rotation-induced component must be added to the residual gravity component; however, since this component is almost two orders of magnitude below the resultant residual acceleration component, there would appear to be no significant penalty from rotating the furnace from a disturbance standpoint. See Figure 3.

Based on a limiting tangential acceleration of 1.6×10^{-7} g, the minimum time to reach w_{avg} from a standstill is 166 sec. Angular velocity and acceleration values based on a sinusoidal air drag variation during the orbital period have also been estimated. The maximum angular velocity based on a sinusoidal air drag force variation is 8.21×10^{-4} rad/sec, which produces a maximum normal acceleration component of 3.55×10^{-8} g. The maximum resultant acceleration due to furnace rotation is 1.2×10^{-7} g. A plot of the total rotation-induced acceleration imposed on the furnace is shown in Figure 4.

Assuming a more optimistic estimate of air drag variation from3×10^{-7} to3×10^{-8} g (or a one order of magnitude difference in the maximum values of air drag and gravity gradient), the furnace is required to rotate from 0 to 5.5 deg. The maximum acceleration imposed on the sample by this rotation is 2.8×10^{-10}g.

II. PASSIVE VERSUS ACTIVE ORIENTATION

Because of possible cost and space impacts, a passive alignment system has also been investigated. A passive system will not actively track the residual gravity vector; however, the furnace will still be gimballed to allow orientation with a predetermined "average" g-vector direction that will yield the minimum off-axis disturbance. The passive system will save costs because of the lack of a drive system, drive control electronics, and a dedicated

Based on a worst-case assumption of an air drag component of $3 \times 10^{-6}g$:

$$\phi = \frac{0.66 \text{ radians}}{22 \text{ min.}} = 0.030 \text{ radians / min} = 5.0 \times 10^{-4} \text{ radians / sec.}$$

$$a_n = 1.7 \text{ ft} \times (5.0 \times 10^{-4} \text{ rad/sec})^2 / 32.2 = 1.3 \times 10^{-8}g$$

$$\phi_1 = \tan^{-1}(3 \times 10^{-7}g / 3.2 \times 10^{-6}g) = 5 \text{ deg.}$$

$$\phi_2 = \tan^{-1}(3 \times 10^{-6}g / 3.2 \times 10^{-6}g) = 44 \text{ deg.}$$

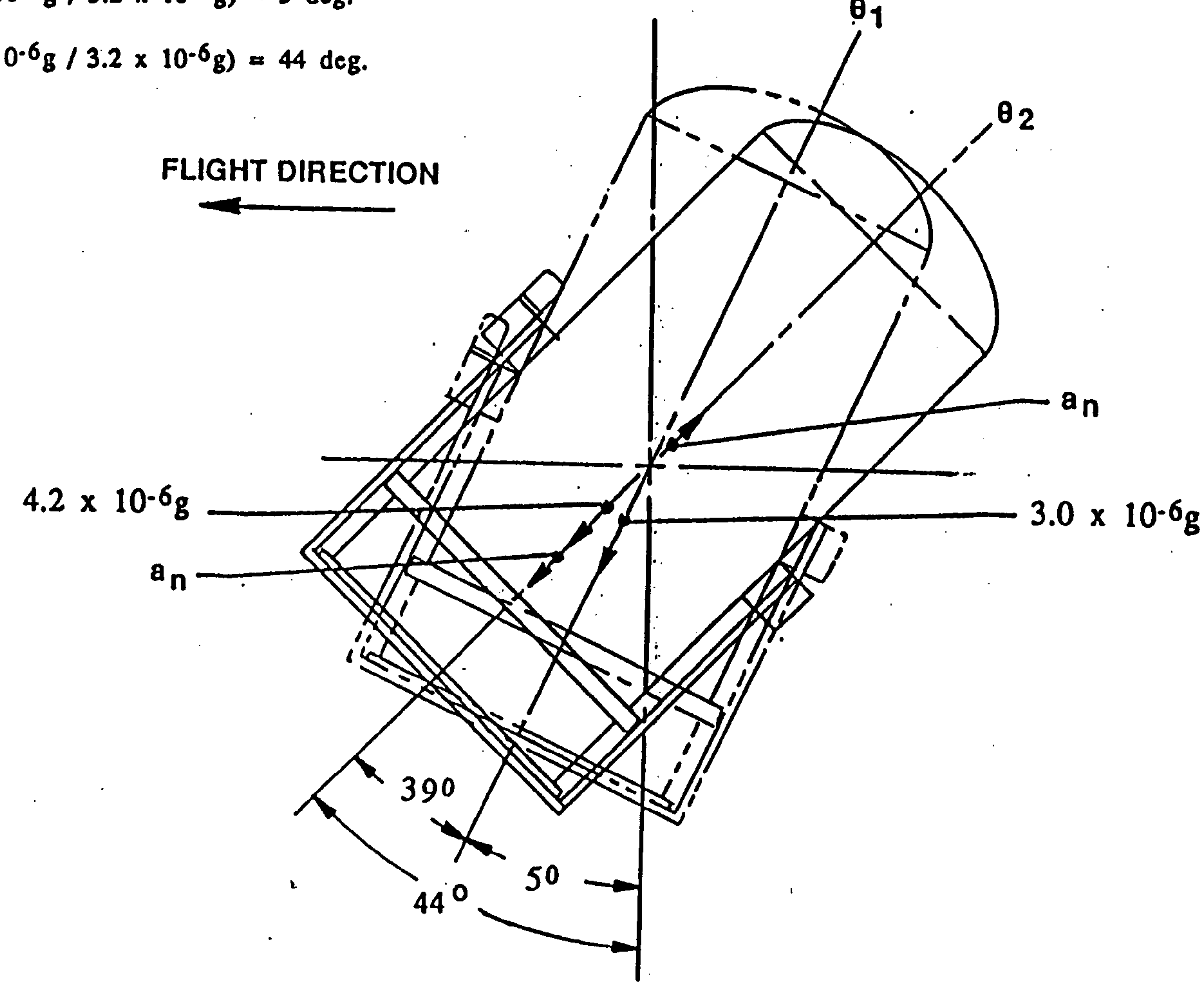
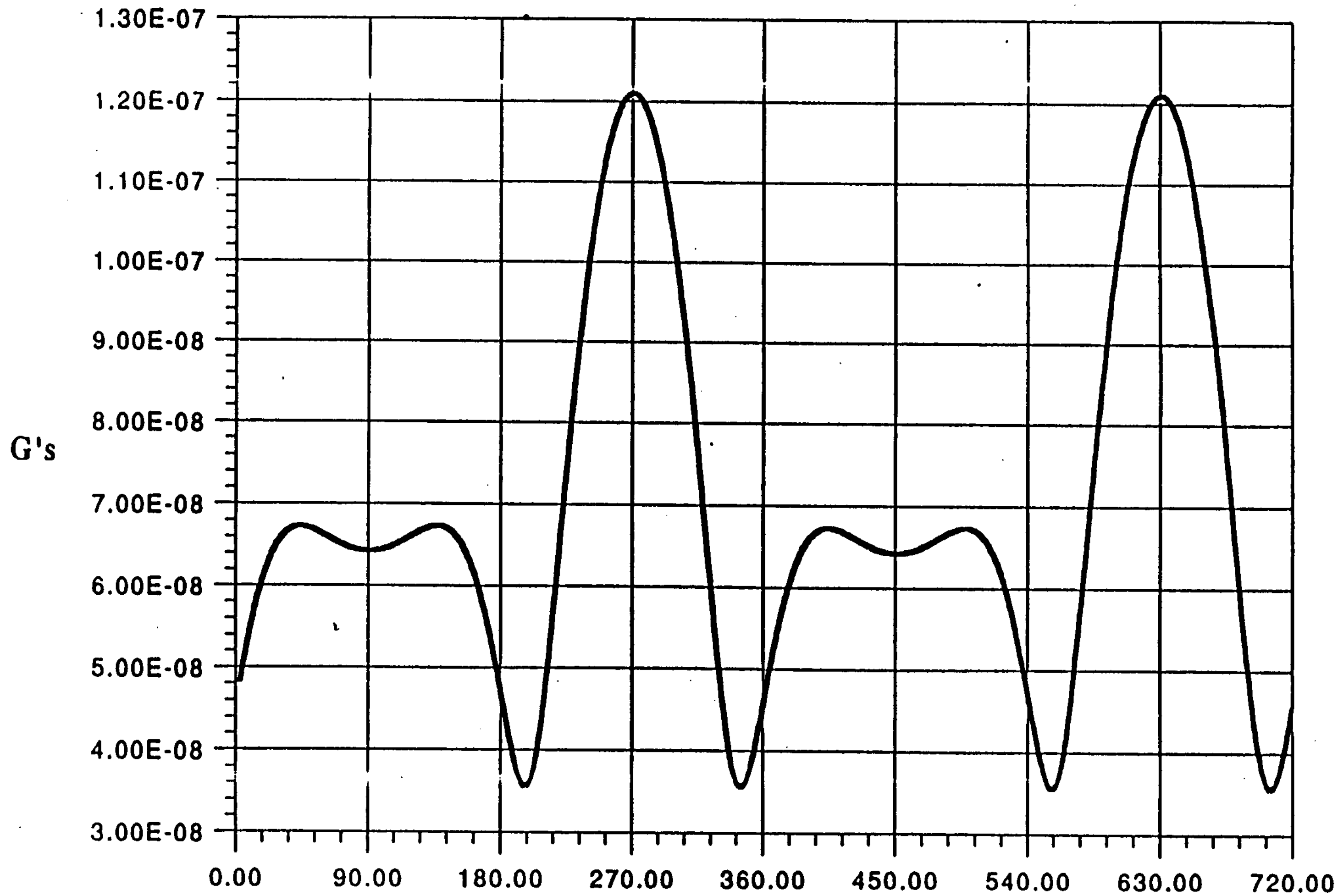


FIGURE 3 WORST CASE FURNACE ROTATION & ACCELERATION



ONE ORBITAL PERIOD

ROTATION INDUCED ACCELERATION
WORST CASE

FIGURE 4

accelerometer system. A passive system could be designed to align with the gravity-gradient component only (rotation on one axis only) or align with the resultant of the gravity gradient and the average air drag component (rotation on two axes).

Alignment with the gravity-gradient component only will produce a cyclic off-axis acceleration equal to the air drag component. Fixed alignment with the average (worst case) air drag vector orientation at 44 deg from the Earth direction axis will produce a maximum off-axis acceleration component ~ equal to the gravity gradient component when the air drag is at a minimum, therefore the furnace should be positioned at the midpoint between the two vectors to minimize the off axis acceleration component. See Figure 5. Fixed alignment with the average air drag force position (2.5 deg), if the maximum air drag force is 3×10^{-7} g, yields an off-axis acceleration component of 5×10^{-7} g.

The passive-active system trade will be determined by the maximum air drag force, the orientation system tracking accuracy, and the maximum off-axis acceleration component allowed by the science requirements. Three cases are examined.

<u>Case 1</u>

a) Air drag varies from 3×10^{-6} to 3×10^{-7} g.

b) Tracking accuracy is 1.0 deg.

c) Gravity gradient is 3×10^{-6} g.

d) Two standard rack spaces are available.

These conditions yield a maximum off-axis acceleration component in excess of 1.45×10^{-6} g if the furnace is in a stationary position 25 deg from the Earth direction axis (this is the rotation midpoint position). This is in excess of the maximum off axis component of 1.6×10^{-7} g specified in the SCRD. The resultant position of the two dominant acceleration components varies from ~5 to 44 deg. A tracking accuracy of ±1.0 deg, if an active system is incorporated, will produce a maximum off-axis error component of 7.3×10^{-8}g.

Case 2

a) Air drag varies from 3×10^{-6} to 3×10^{-7} g.

b) Gravity gradient is 3×10^{-6} g.

c) Tracking accuracy is 1.0 deg.

d) Only one standard rack space is available

These conditions produce a maximum off-sample axis acceleration component of 1.9×10^{-6} g if the furnace is in a stationary position 18 deg from the Earth direction axis (this is the maximum rotation angle in the standard rack). This value is in excess of the 1.6×10^{-7}g value specified as the maximum off axis acceleration specified in the SCRD. The 1.0-deg tracking accuracy if an active system is incorporated will produce a maximum off-axis acceleration component of 1.75×10^{-7} g.

Case 3

a) Air drag varies from 10^{-6} to 10^{-7} g.

b) Tracking accuracy is 1 deg.

c) Gravity gradient is 3×10^{-6}g.

These conditions are currently considered to be the most realistic. The resultant position of the two dominant acceleration components varies from 2 to 18 deg. This variation falls within the space envelope provided by the standard rack, therefore active tracking is possible within the standard rack space. The current requirements document specifies a maximum off-axis accceleration component of 1.6×10^{-7}g below 0.020 hz. If a passive system is utilized, fixed alignment on the air drag axis at an "average" position of 11 degrees off the earth direction axis yields a periodic off axis component of 3.9×10^{-7}g which is slightly above the requirements. These statements are made based on the assumption that the pitch Torque Equilibrium Attitude (TEA) lies along the velocity vector of the space station.

Pitch TEA's have been reported to vary from -11 to +20 degrees depending on the station configuration. A positive pitch TEA reduces the furnace air drag tilt angle with respect to the longitudnal axis of the lab module while a negative pitch TEA increases the required tilt angle on the air drag axis. The TEA at Man Tended Capability (MTC;June 1996) has been estimated at +20 degrees. The rotation angle in the rack for alignment with the resultant of the peak air drag vector and the gravity gradient vector will then be 18 degrees - 20 degrees or -2 degrees. The TEA at Permanent Manned Capability (PMC;August 1997) is estimated at -6 degrees. The rotation angle in the rack for alignment with the resultant of the peak air drag vector and the gravity gradient vector will then be 18 degrees - (-6) degrees or 24 degrees. This alignment angle moves the furnace back out of the space provided by the standard rack envelope if active tracking is incorporated. The standard rack space tilt angle limit of 18 degrees imposes an off-axis acceleration component of 3.3×10^{-7}g on the sample during peak air drag. These estimates are based on a 3 to 1 gravity gradient to peak air drag ratio (3×10^{-6}g gravity gradient and 1×10^{-6}g peak air drag).

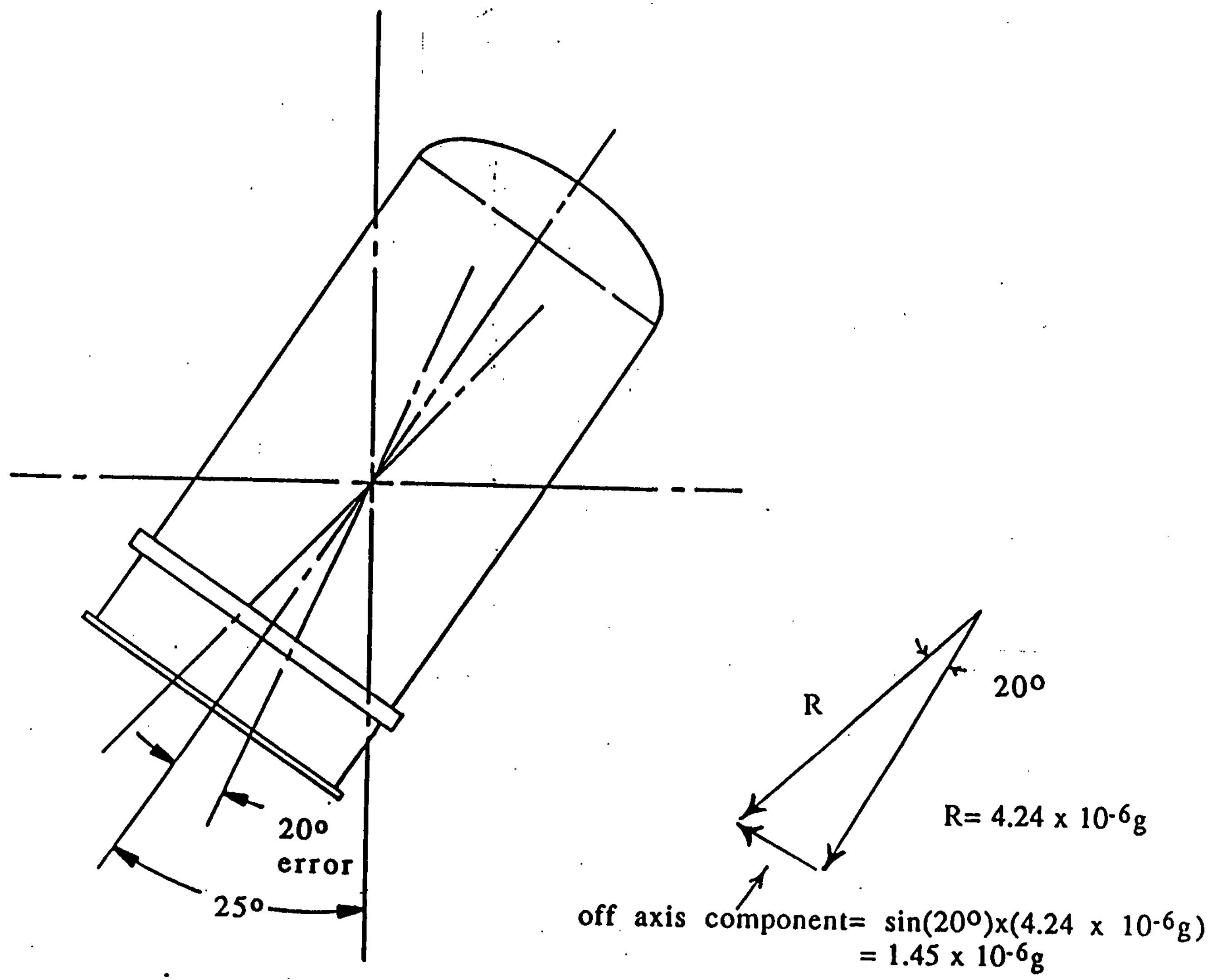


FIGURE 5 ERROR PRODUCED BY A PASSIVE SYSTEM

III. FURNACE ORIENTATION SYSTEM

Several concepts for orientation systems have been explored. The basic design parameters for an active system are as follows:

- ±18-deg movement required on a radial plane through the lab module
- up to 45-deg of movement for air drag compensation - this will probably require a special rack space at least 64 in. wide
- Minimum or no entry into the lab aisle space
- The system must accommodate various sized and shaped furnace modules
- Hose and electrical connection provision
    - Fluid connection
    - Inert gas
    - Heater power
    - Vacuum
    - Instrumentation.

The space requirements for rotation about two axes are shown in Figure 6. The space required will depend on the furnace diameter, length and the required angles of rotation. The rotation angles shown in the figure are based on a 24-in. diameter furnace module, 54 in. long. It becomes immediately obvious that furnace module containers as large as CGF will not be compatible with the system. Furnace modules will probably be required to be at least 25 percent smaller in length. This may require a corresponding reduction in sample length depending on the particular furnace design.

The impact of a sample size reduction on the science requirements will need to be determined. If 45-deg rotation on the air drag alignment axis is required, it will be necessary to use two standard rack spaces or at least 64 in. of wall space depending on the furnace size.

Concept I, shown in Figure 7, consists of a tilt stage at the base of the rack for gravity-gradient alignment and the second rotation point for air drag alignment located at the furnace CG position. An L-shaped structure connects the tilt stage and the rotation gimbal. This configuration has a space disadvantage.

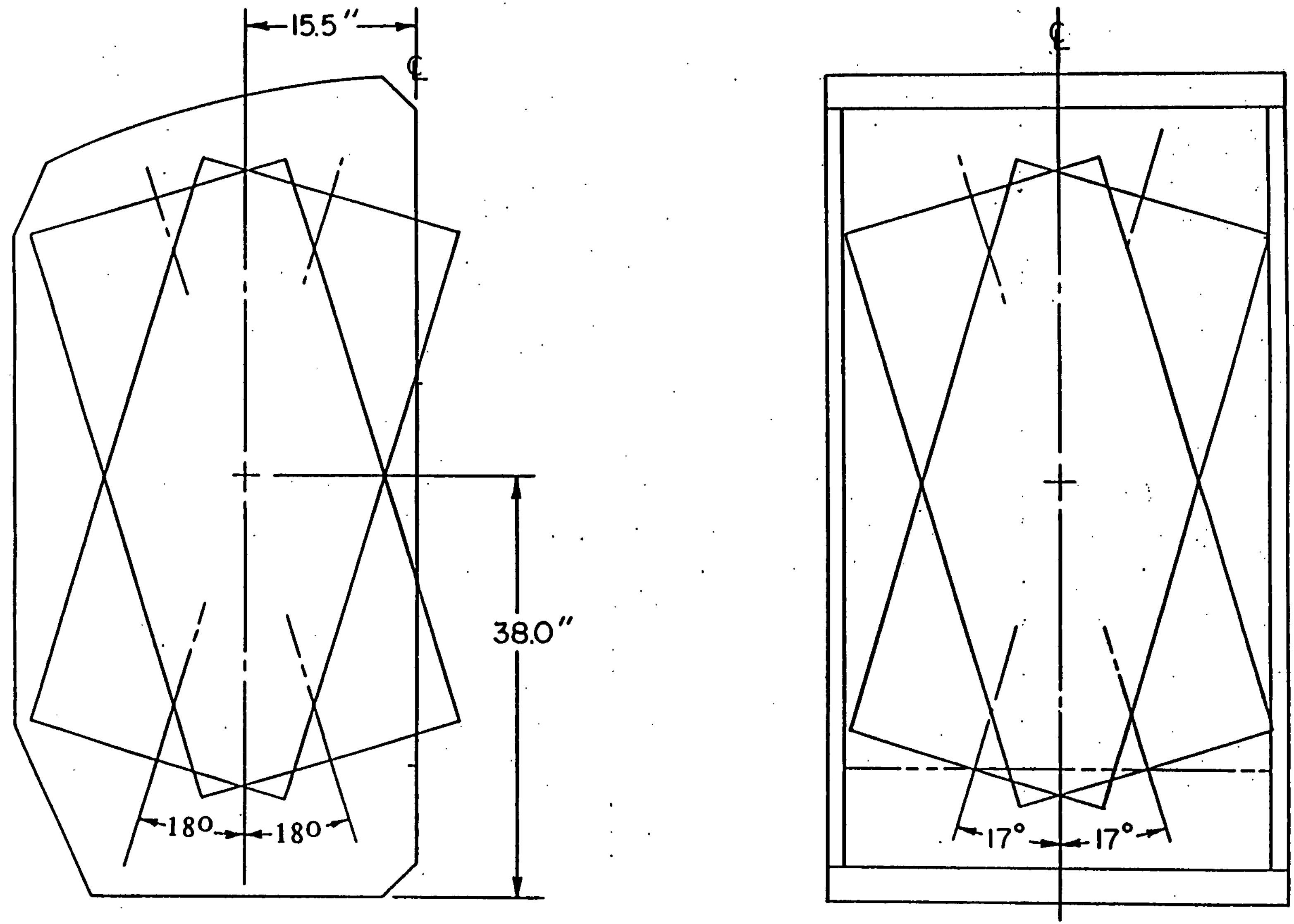


FIGURE 6 MAXIMUM TILT ANGLES - DOUBLE RACK

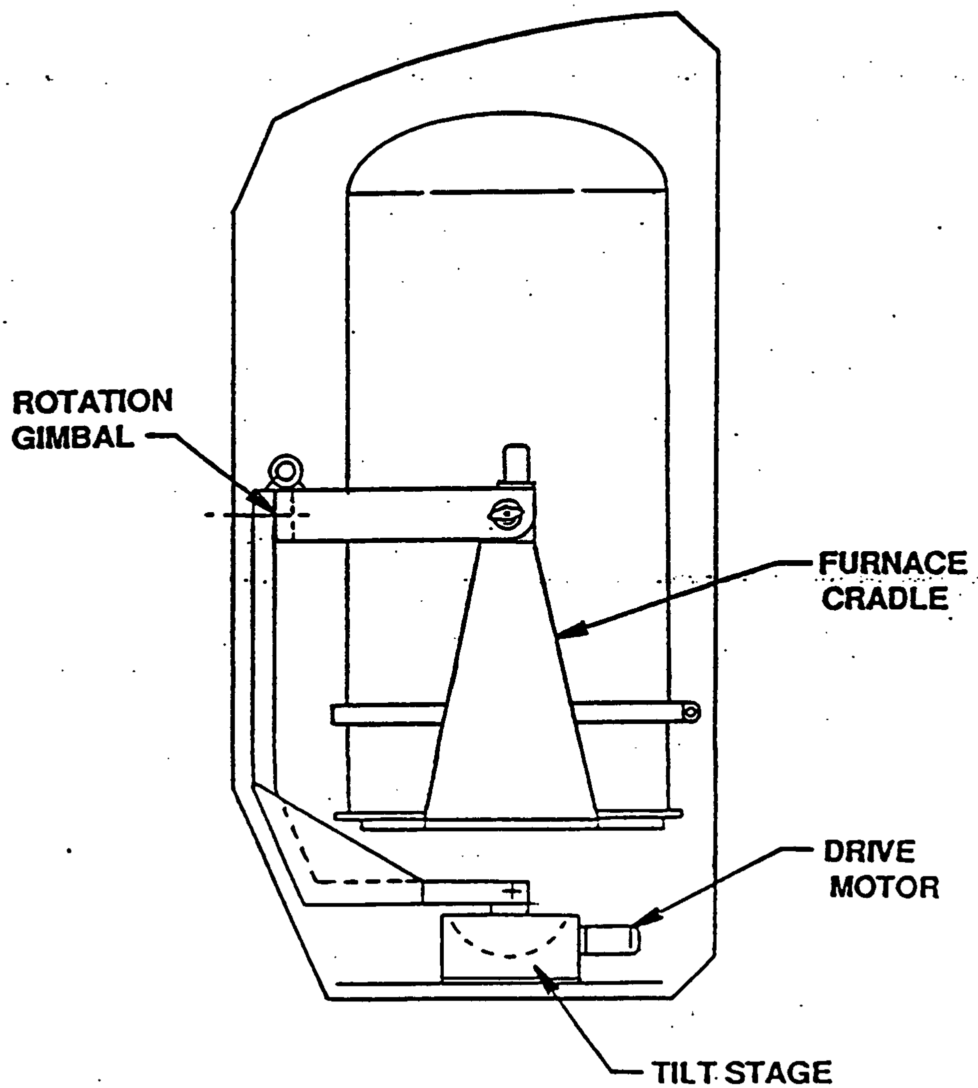


FIGURE 7 CONCEPT 1

The base stage and the arm from the base to the upper rotation gimbal intrude on the furnace space and limit the rotation angles, furnace length, and furnace diameter.

Concept II places both of the rotation gimbals in the same plane. See Figure 8. The gimbal structure is still supported from the base of the rack. This configuration is more space efficient than Concept I and allows both rotation points to be located in the same plane.

Concept III places both rotation points in the same plane, as in Concept II, but uses a special rack which allows mounting of the longitudinal (air drag) rotation point on the back wall of the rack. See Figure 9. This configuration allows a larger tilt angle and/or furnace module size by elimination of the rack base support arm. However, this configuration will require the design and construction of a special lab rack.

If the standard rack space is used, the furnace length is limited to 34 in. with a 17-in. diameter (EAC) container (assuming 45-deg air drag rotation). See Figure 10. Further reductions in furnace diameter will only yield a length increase of 4 in. Based on the standard rack depth and a 18-deg gravity-gradient alignment angle, a 24-in. diameter (CGF size) furnace container is limited to a length of 54 in. With this size furnace container, 59 in. of wall space is required to accommodate a 45-deg rotation. See Figure 11. The EAC container diameter of 17 in. will allow a furnace container length of approximately 64 in. with the standard rack depth and an 18-deg gravity-gradient alignment tilt angle.

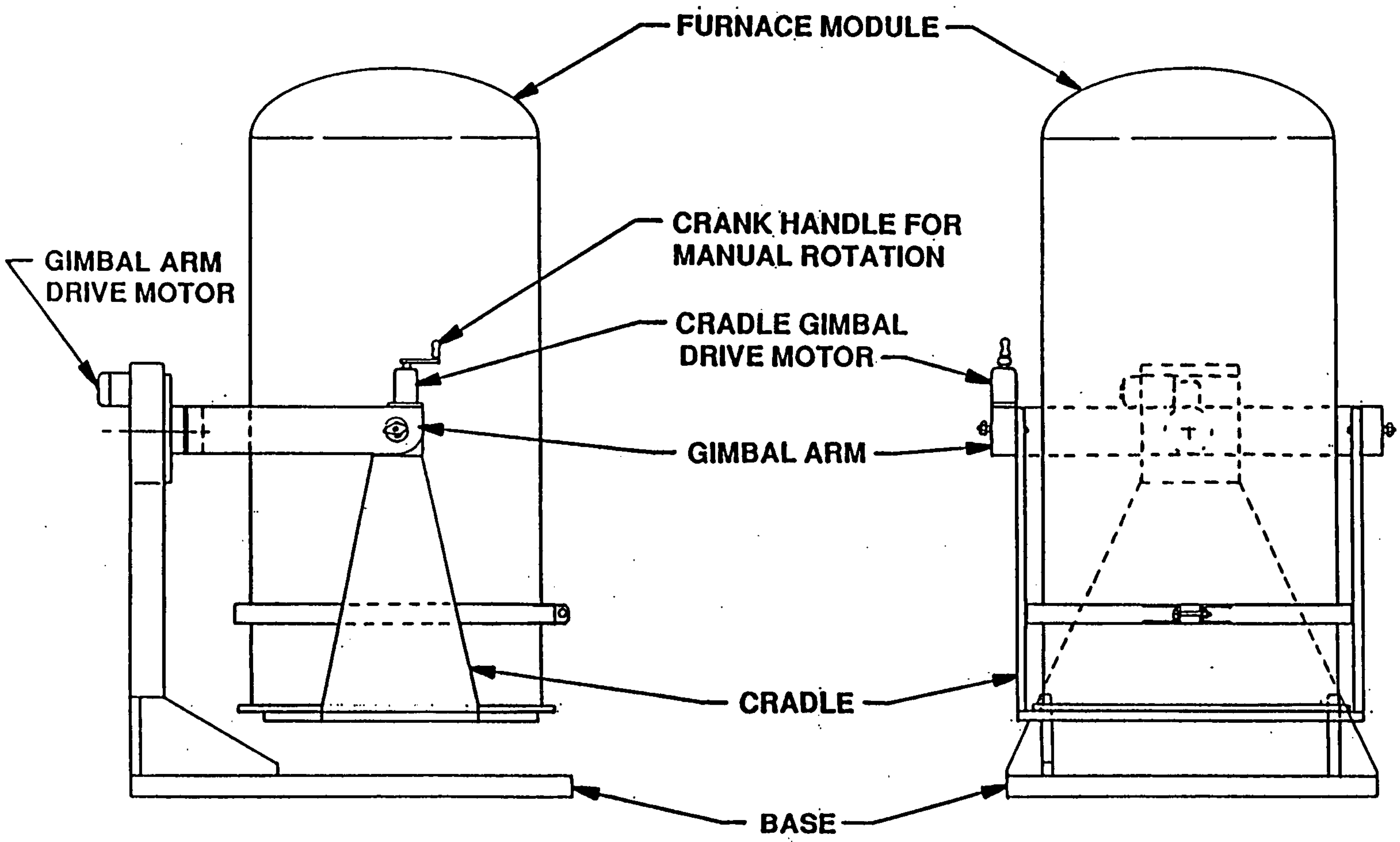


FIGURE 8 CONCEPT 2

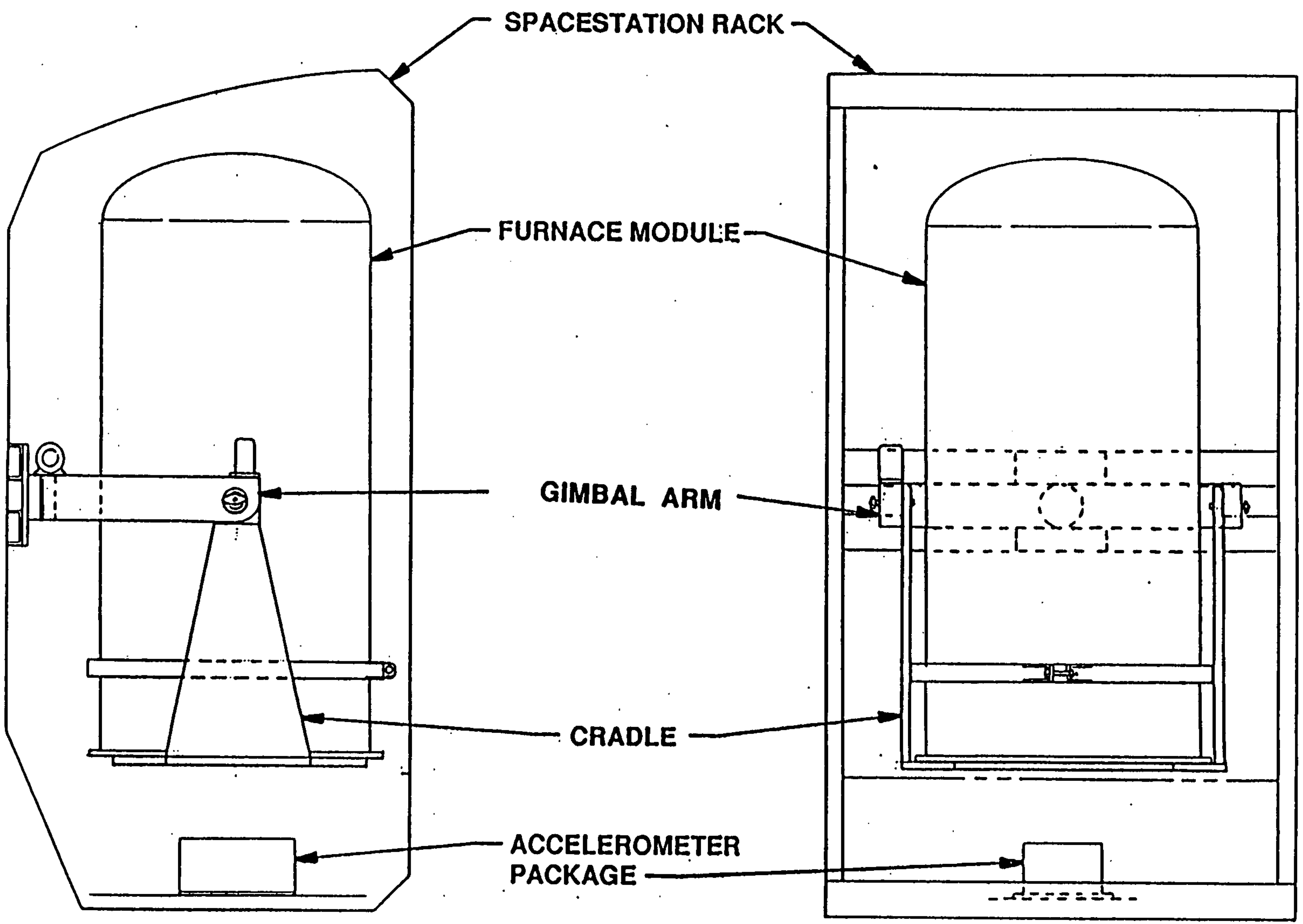


FIGURE 9 CONCEPT 3

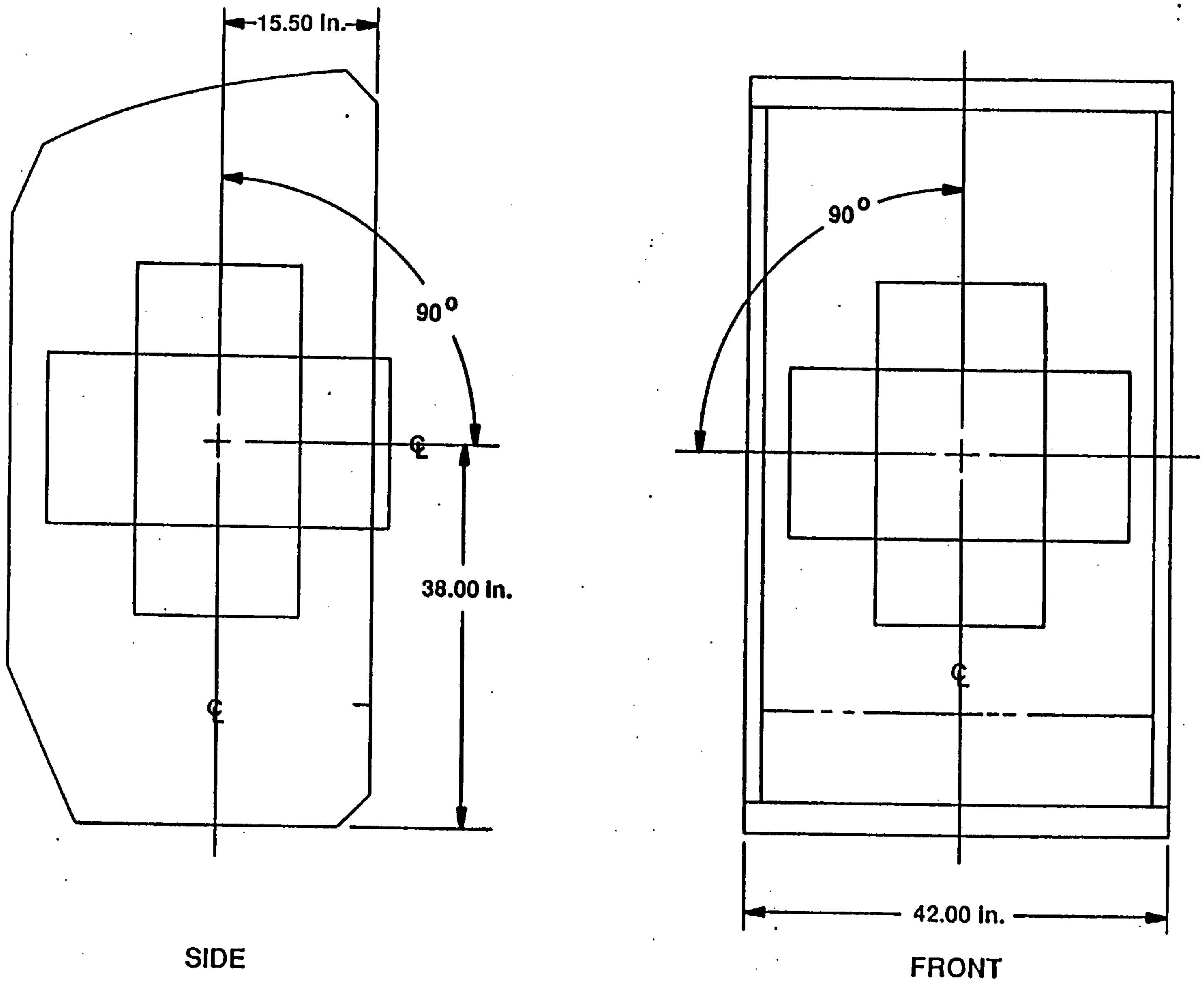


FIGURE 10

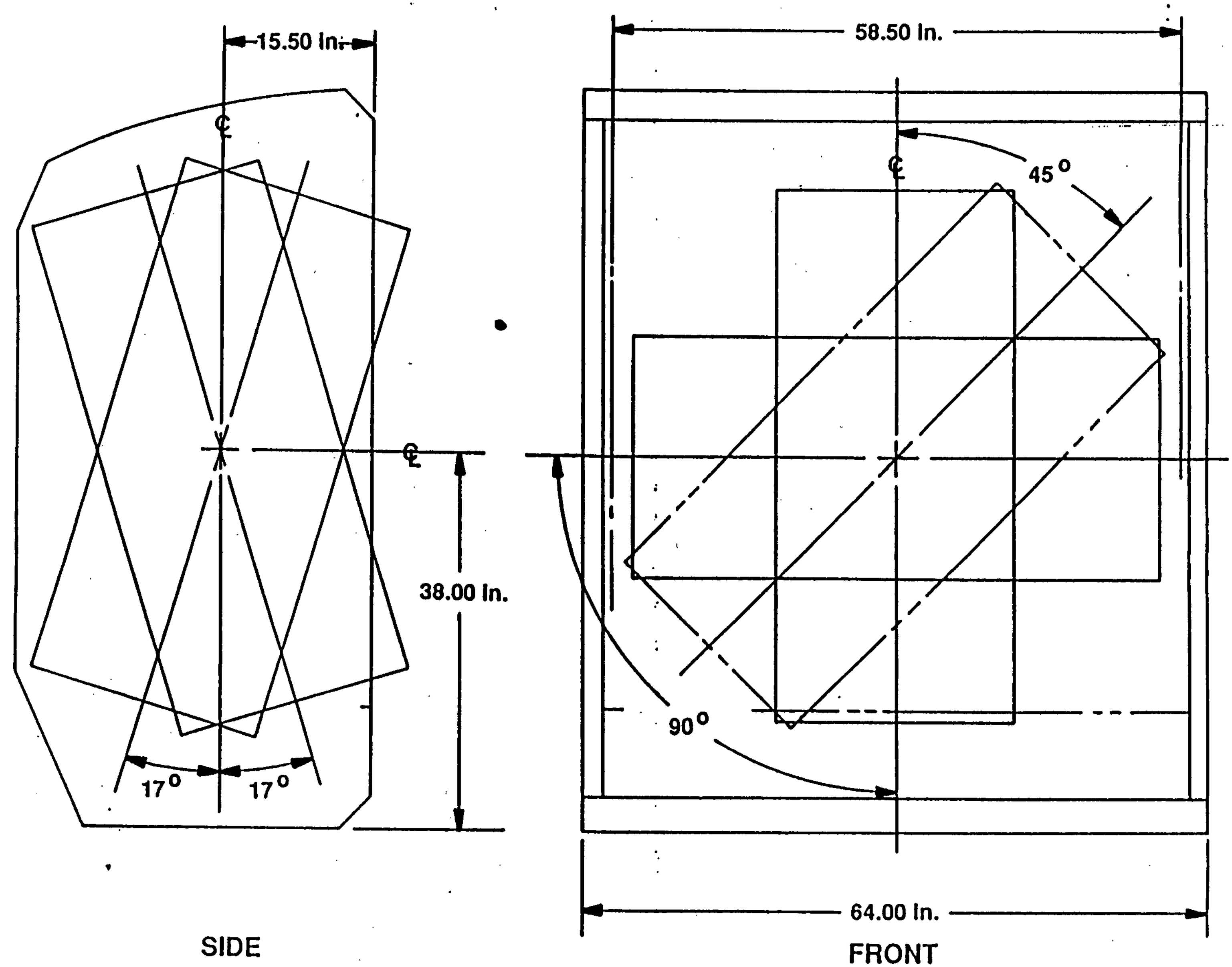


FIGURE 11 · FURNACE SPACE REQUIREMENT

The impact of the reductions in sample diameters and lengths on the science requirements of potential experiments needs to be examined. The orientation system will also have impacts on the design of an automated sample exchange system and may possibly rule out the inclusion of such a system.

A special wide rack poses the additional problem of entry into the lab module through the 50-in. wide hatch. The problem requires further examination. One possible concept, shown in Figure 12, would utilize a folding structure that would fit within the space of two racks. The furnace gimbal assembly would be mounted on a "backbone" structure. This structure would have foldout arms, which would connect with the lower rear attach points in the lab module. This same concept is shown tilted forward in the removal configuration in Figure 13.

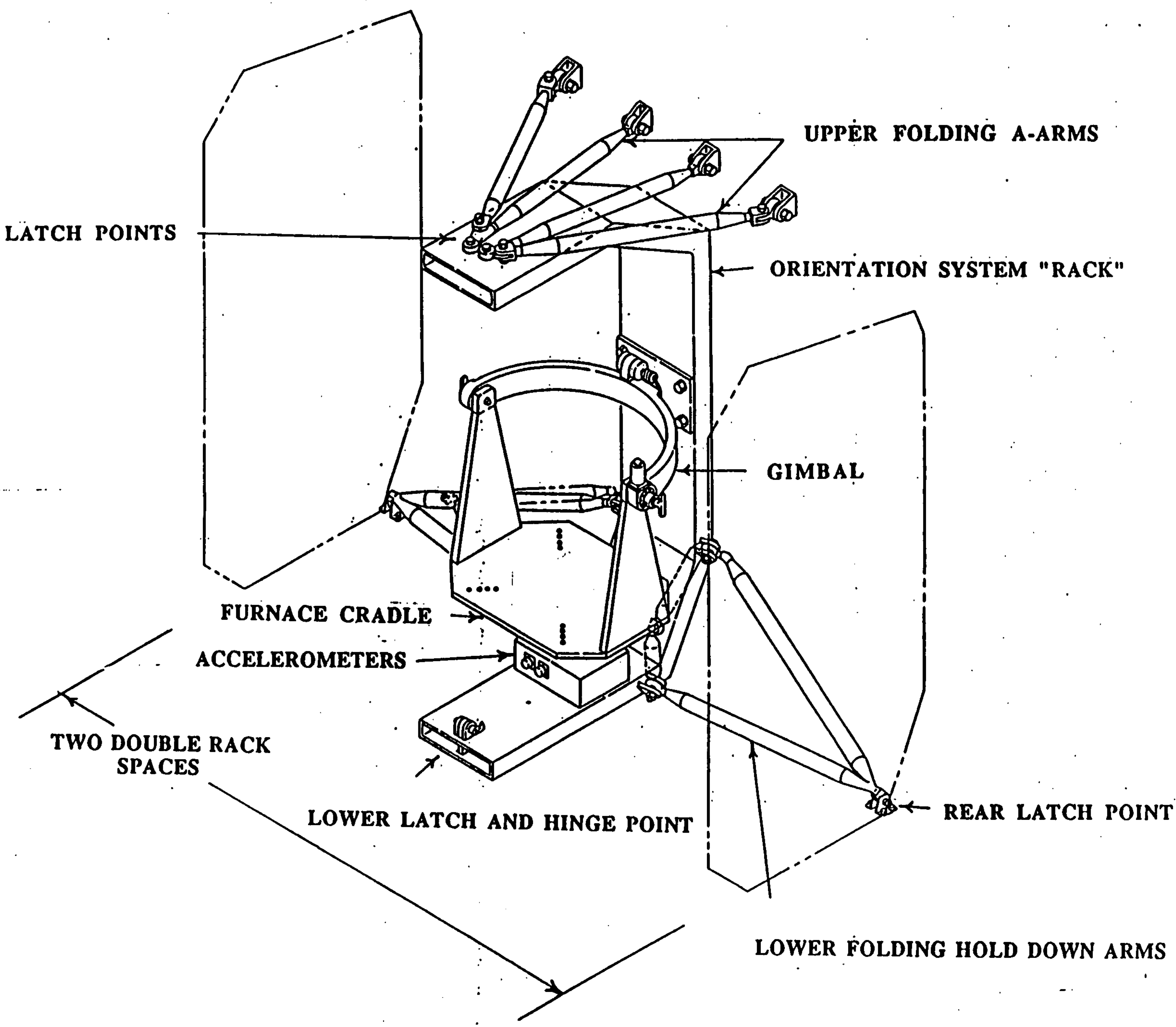
The 45-deg rotation requirement in the air drag correction plane may be reduced to less than 18 deg if the air drag component is always less than the gravity gradient componenet by at least a 3 to 1 ratio and if the sum of the pitch at the TEA and air drag tilt angle is less than 18 degrees (negative TEA pitch changes increase the rotation space requirement; positive TEA pitch angles decrease the space requirement.). An 18-deg maximum rotation angle will allow the orientation system to fit within the standard rack space. Furnace module length will still be restricted to 54 in. with a 24-in. diameter.

Since the furnace enclosure cans are likely to be thin walled, a furnace support or cradle will need to be provided to support the furnace module at the base. The cradle must be designed to provide on-orbit furnace module interchangeability. The concept for furnace module changeout is shown in Figure 14. There are two changeout concepts. One concept uses a furnace module dedicated support cradle. The entire cradle assembly would be changed with the furnace module. The cradle will be designed so that the distance between the rotation hubs accommodates the largest diameter furnace module envisioned.

The cradle would be located by two splined and removable axles. Module changeout would involve removing a locking pin, retracting both axles through the gimbal spindles, and removing the cradle.

All hose and electrical connections would be broken at the support cradle.

FIGURE 12
FURNACE ORIENTATION SYSTEM



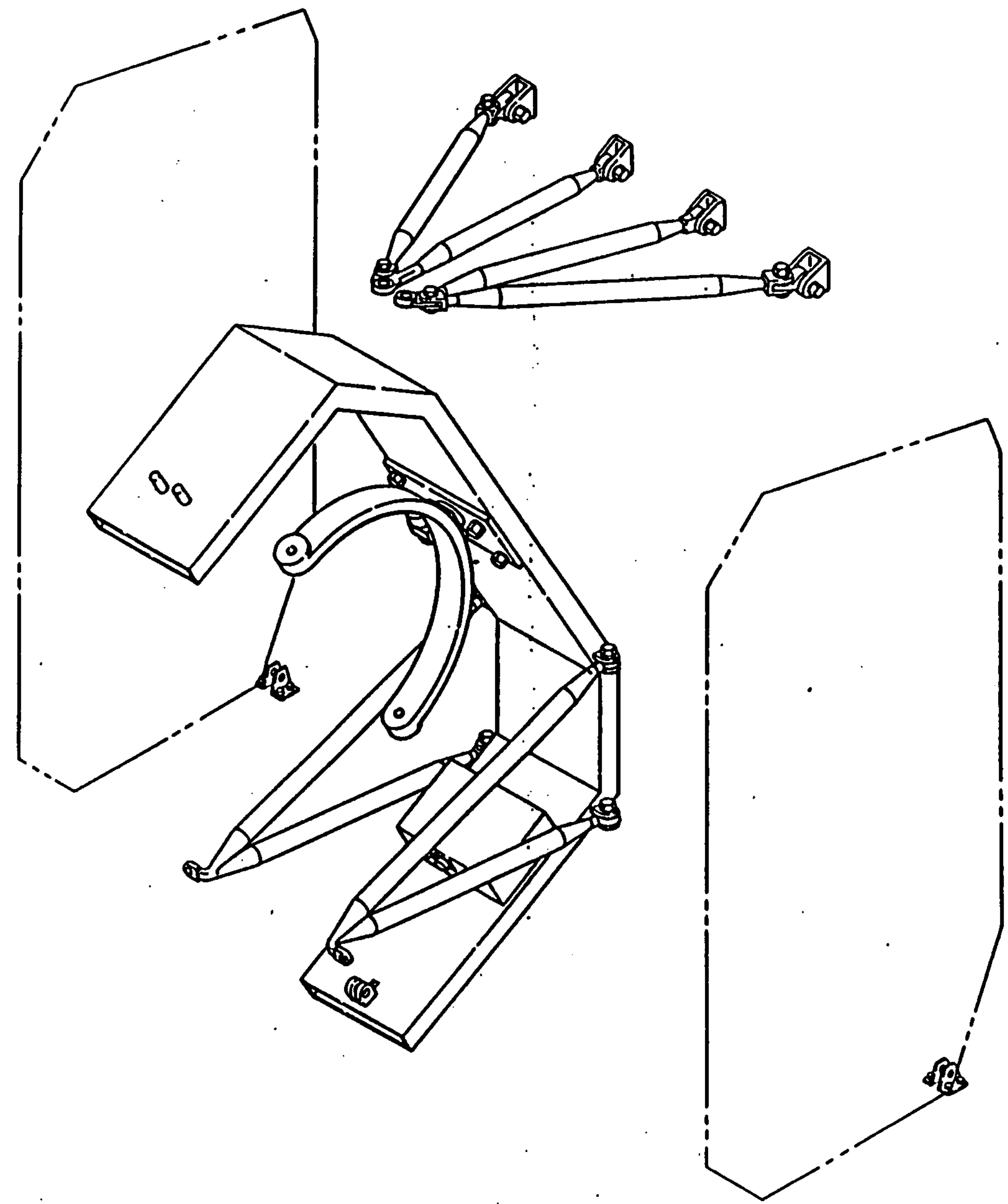


FIGURE 13 RACK REMOVAL CONFIGURATION

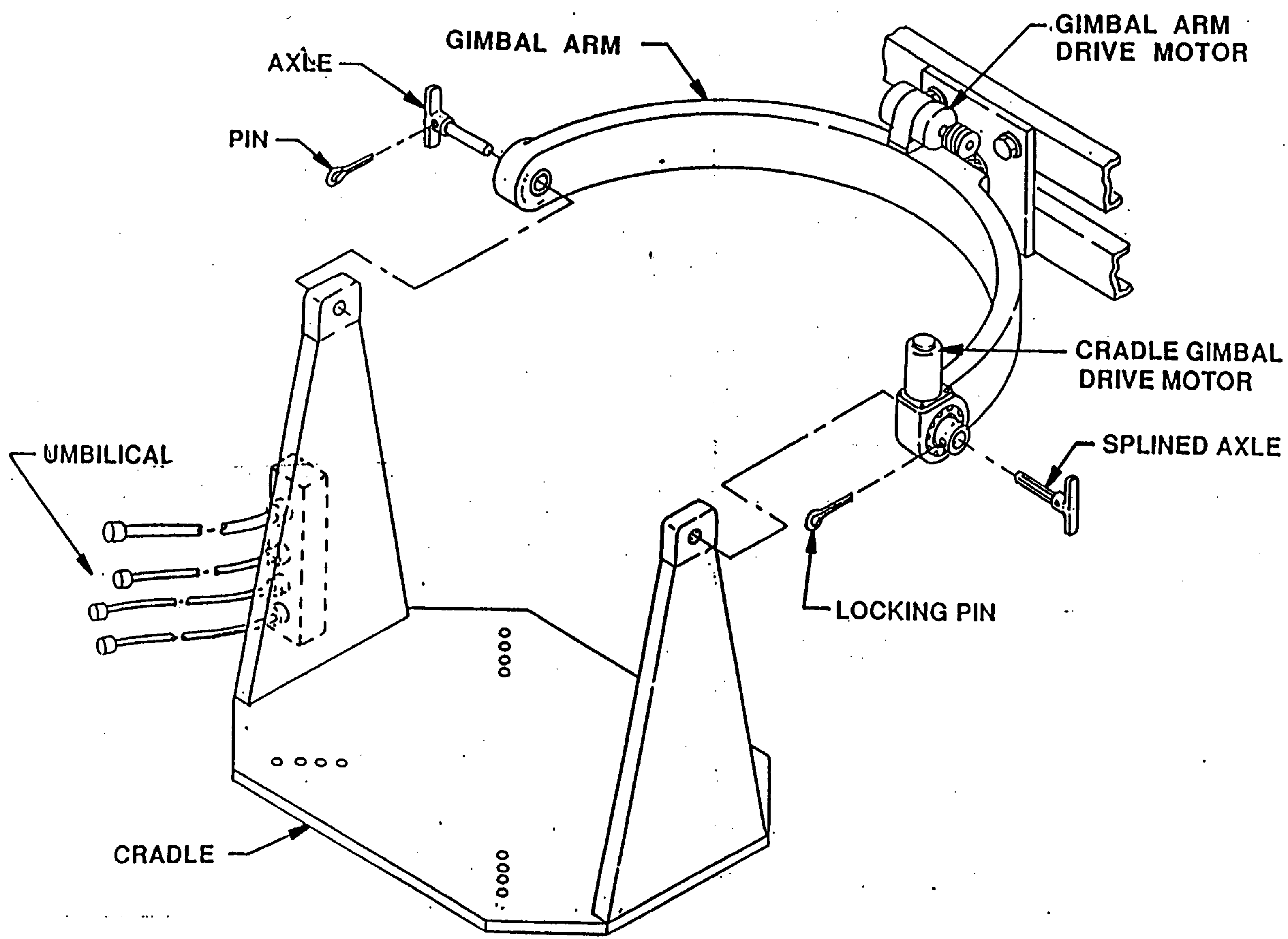


FIGURE 14 ORIENTATION GIMBAL CONCEPT

In the second concept, the support cradle is integral with the rotation gimbal. The front of the cradle is open to allow removal and insertion of the furnace module. Each furnace module would require a base adapter plate for connection with the cradle baseplate. Hose and electrical lead breaks would be made at the base of the furnace module. This system offers potentially easier module changeout, but may introduce design restraints on the various furnace modules.

IV. SUBSYSTEM REQUIREMENTS

- Accelerometer Subsystem
  - 10^{-8} g sensitivity at 10^{-3} Hz (one order of magnitude less than the minimum acceleration to be measured)
- Accelerometer Signal Conditioners
  - Filtering and Amplification
- Accelerometer Data Management System
  - Processing of signal conditioner output
  - Determination of residual g-vector orientation
  - Storage of pertinent acceleration data
- Drive Motor Power Supply and Control System
- Drive Motor System and Position Sensors - positioning accuracy to 1.0 deg
- Flexible connection system
- Accelerometer calibration system
- Accelerometer vibration isolation system.

V. SAFETY ISSUES AND HAZARDS

- Flexible connection failure
  - Fluid and gas connection
  - Power connection
  - Vacuum connection
  - Instrumentation

- Failure of the rotation system drive mechanism may allow unrestrained rotation of the furnace module

- Crew entry into the furnace motion space. It will probably be necessary to provide torque limiting slip clutches in the rotation mechanism

- Crew injury during furnace module changeout.

- Touch Temperature limitations on furnace components protruding out of the rack envelope.

TECHNOLOGY DEVELOPMENT ISSUES

I. ACCELEROMETER SYSTEM

A three-axis accelerometer system is required for the purpose of determining the residual g-vector direction and magnitude. The accelerometer system must be capable of measuring accelerations of 10^{-8} g at frequencies of 10^{-3} Hz. The accelerometer should have a resolution one order of magnitude greater than the minimum acceleration. Preliminary investigations (TBE Workpackage I) indicate the Sundstrand ASDA and the Bell MESA are the only currently available accelerometers capable of coming close to meeting these requirements. The Sundstrand QA-2000 and the Bell Model XI are marginal at best (10^{-6} g). The Sundstrand ASDA appears to be capable of acheiving 5 x 10^{-8} g if a passive vibration isolation system is incorporated. The Bell MESA appears capable of measuring accelerations of less than 10^{-8}g but may require an active vibration isolation system. Tests indicate the Bell MESA accelerometer may have problems with limited dynamic range and will require extensive vibration isolation. Accelerometer testing at TBE has been terminated because of a stop-work order on Workpackage I. The requirement for a dedicated furnace orientation system accelerometer system is eliminated if an accelerometer system is included as part of the furnace facility or the US lab module. If a mapping system is utilized, it will not be necessary to provide an accelerometer station at the orientation system location.

II. ACCELEROMETER CALIBRATION SYSTEM

Accelerometers such as the Sundstrand QA-2000 have exhibited bias drifts as high as 3 x 10^{-7} g/h. Therefore, a periodic calibration technique must be developed to ensure bias correction. Null bias calibration may be achieved by placing the accelerometer in a gimbal structure and rotating the accelerometer 180 degrees. Any difference in the accelerometer reading after rotation is the null bias. The rotation gimbal may also be used for scale factor calibration by rotating the accelerometer at a controlled rate and measuring the centripetal acceleration.

III. ACCELEROMETER VIBRATION ISOLATION SYSTEM

Either an active or passive vibration isolation system will be needed to prevent accelerometer saturation at high noise levels.

If an accelerometer subsystem is incorporated in the SSFF or the Acceleration Mapping System is reincorporated in the Space Station Freedom, then a dedicated accelerometer system for furnace orientation will not be required.

CONCLUSIONS

This study has determined that a furnace orientation system is feasible. Either an active or passive system may be utilized depending on the tolerance in the maximum off axis acceleration specified in the SCRD and the space requirements of the US lab module. The recommended configuration is a passive system scarred for conversion to an active system at some later date. Conversion will require replacing the hand cranks at the two rotation points with drive motors, installing drive control electronics in the core rack, and routing of power and control cables. The concept for an active tracking system is illustrated in Figure 14. The following design features are incorporated in the active tracking system:

- Rotation gimbals in a common plane.
- Furnace modules are base mounted.
- The air drag correction gimbal is wall mounted.
- The system will accept a 24-in. diameter, 54-in. long experiment container (provided rack space requirements are met).
- Furnace module umbilical connection breaks are made at the support cradle.
- Gimbal rotation points (when active tracking is incorporated) are driven by stepper motors in microstepping mode
- Rotation points are driven through worm and anti-backlash worm gears incorporating a self-locking gear ratio and torque limiting slip clutches. Gear train related noise will need to be investigated.[1]

[1] There do not appear to be any problems with bearing related noise or stiction at the low angular velocities. It is recommended that a wet lubricant be used, that the bearings be preloaded, and the bearings be sized to allow at least one complete ball rotation.

The conclusions are based on the following assumptions:

- The U.S. lab module is located at the position shown in Figure 2.

- 3×10^{-6}g gravity gradient component.
- The Space Station Freedom exhibits no roll during orbit.
- The system size is within the Space Station Freedom rack space requirements.
- Sample sizes dictated by the orientation system do not violate science requirement.
- 10^{-3} Hz air drag force variation.

A passive orientation system will not meet the maximum off-axis acceleration of 1.6×10^{-7}g specified in the SCRD with a peak air drag acceleration of 1×10^{-6}g or greater. Positioning the furnace at a "mission averaged" position will result in a peak off axis component approximately 2×10^{-7}g to 3×10^{-7}g higher than the specified maximum. It is recommended that the requirements document specification be modified to correspond with these estimates for a passive orientation system.

At the time when active tracking is installed, it is recommended that each drive motor be provided with a hand crank for manual operation of each rotation point in the event of a drive system failure. If an acceleration mapping system is not incorporated in the Space Station Freedom, the accelerometer package should be located as close as possible to the furnace module, preferably directly under or over the orientation cradle.

PHYSICAL ACCOMMODATION REQUIREMENTS FOR AN ACTIVE POSITIONING SYSTEM

Component	Mass (kg)
Furnace Cradle Assembly	10
Gimbal Arm	15
Drive Motors (2)	3
Accelerometer Package	10
Gimbal Support Structure/Rack	TBD

Space Requirements:

Worst-Case Assumption Based Configuration - 2 Standard Racks
Optional Configuration - 1 Standard Rack

Power Requirements:

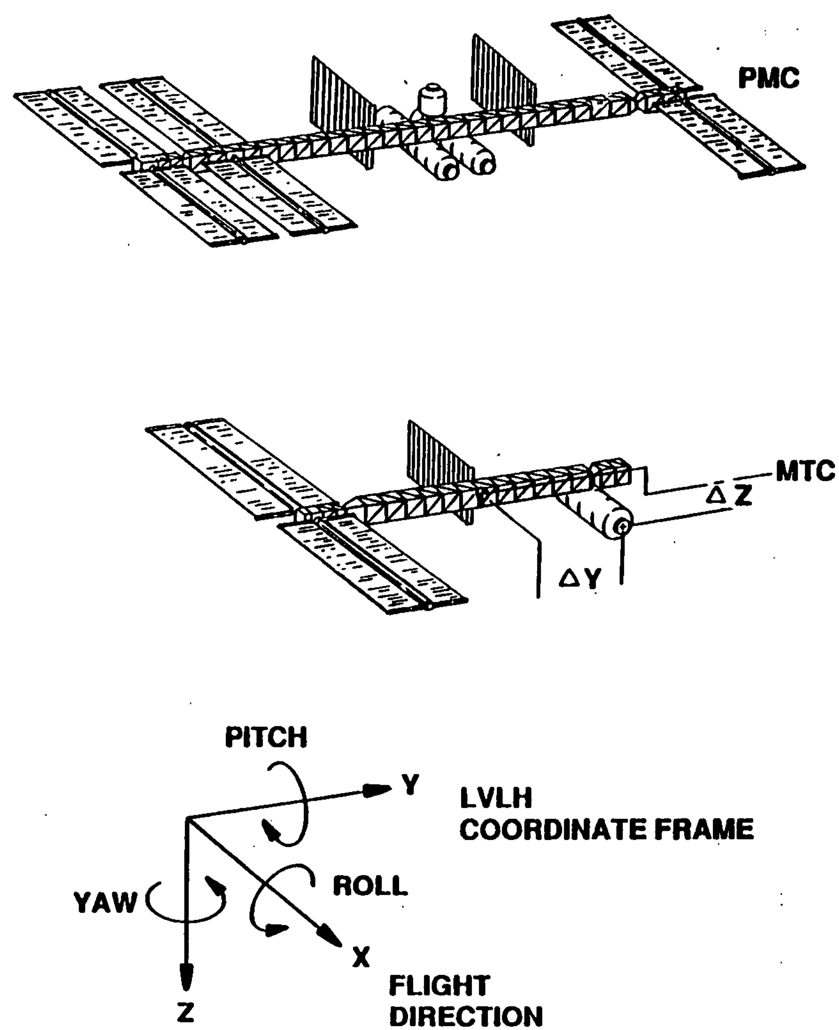
Drive Motors (2) - 50 W
Control Electronics - TBD

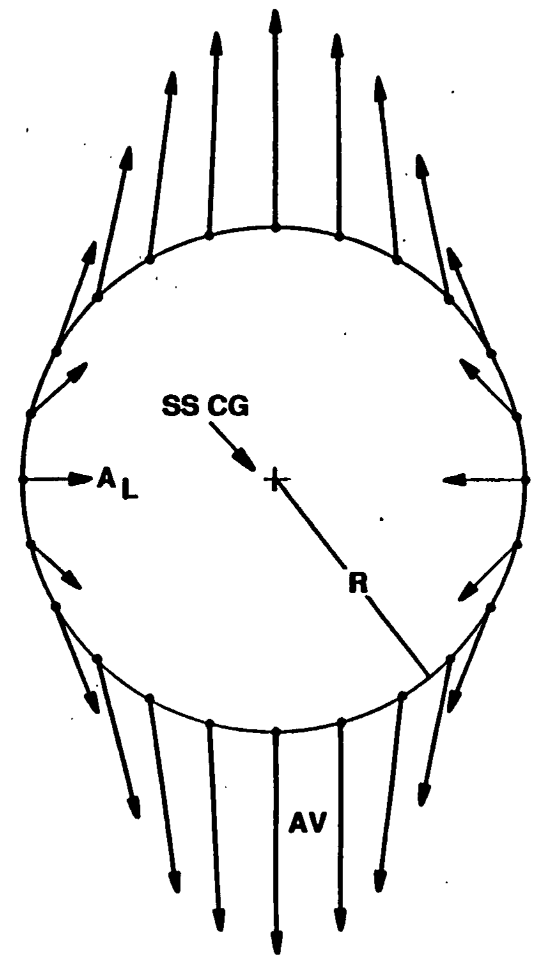
RECOMMENDATIONS FOR FURTHER STUDY

- Orientation system space requirements
- Crew assembly and interaction requirements
- Sample exchange problems
- Cost impacts of a furnace module logistics carrier
- Assembly procedures

We were asked to reassess the furnace orientation requirement for the Science Workshop held on October 28, 1991. The reassessment reflects changes that have occured in the station configuration. The following charts were presented at that workshop.

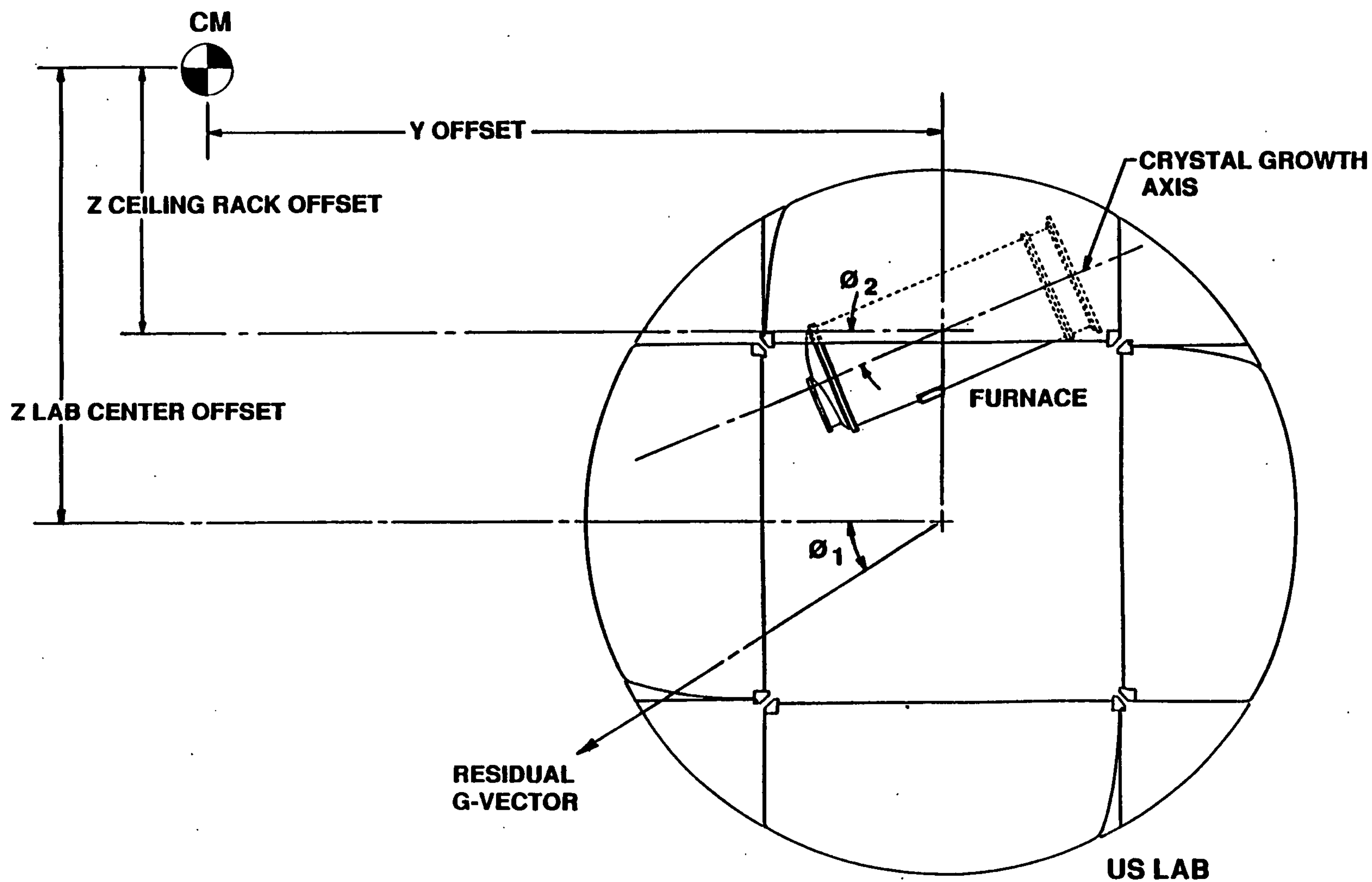
FURNACE ALIGNMENT





GRAVITY GRADIENT ACCELERATION FORCE
IN PLANE PERPENDICULAR TO FLIGHT DIRECTION

FURNACE ALIGNMENT



FURNACE ORIENTATION WITH THE RESIDUAL G VECTOR

- Gravity gradient acceleration dominates - acceleration due to displacement from station center-of-mass
- Air drag acceleration average varies for 0.06 X $10^{-6}g_o$ to 0.1 X $10^{-6}g_o$; 240nm to 225nm reboost point, 4 reboosts per year *
- Centripetal acceleration at pitch drift rate of 0.002 deg/sec is approx. 0.1 X $10^{-6}g_o$ at MTC and 0.05 X $10^{-6}g_o$ at PMC at US lab center*
- Crystal growth axis parallel with residual g-vector - desired condition
- Furnace alignment orientation requirement is effected by position of furnace with respect to station CM and Station Torque Equilibrium Attitude (TEA)
- TEA varies with Station configuration and orbital conditions - balance achieved between aerodynamic torque and gravity gradient
- Current SSEIC study results: MTC mean = 2 X$10^{-6}g_o$, PMC mean = 1.5 X$10^{-6}g_o$; LVLH **flight mode

*SSEIC Report Sept. 1, 1991; does not currently contain resultant direction data
**Station body axes aligned with xyz coordinate system

FURNACE ORIENTATION WITH RESIDUAL GRAVITY VECTOR

- Gravity gradient acceleration is a function of orbital altitude, orbital position, and displacement from station center of mass

$$a_{Gy} = \mu \frac{\Delta y}{r^3} \qquad a_{Gx} = \mu \frac{\Delta x}{r^3} \qquad a_{Gz} = -\mu \frac{2\Delta z}{r^3}$$

$\mu = 3.986 \times 10^{14} m^3/sec^2$

r = earths radius at equator + orbital altitude = $6.619 \times 10^6 m$

- At MTC:
  $\Delta x = 2.5m$, $\Delta y = 13m$, $\Delta z = 3.1m$
  $a_{Gy} = 1.8 \times 10^{-6} g_o$, $a_{Gx} = 3.5 \times 10^{-7} g_o$, $a_{Gz} = -8.7 \times 10^{-7} g_o$
  $ø_{zy} = 64$ deg from z axis, $ø_{xy} = 78$ deg from x axis
  $R = 2.0 \times 10^{-6} g_o$

- At PMC:
  $\Delta x = 4.8m$, $\Delta y = 5m$, $\Delta z = 2.5m$
  $a_{Gy} = 7.0 \times 10^{-7} g_o$, $a_{Gx} = 6.7 \times 10^{-7} g_o$, $a_{Gz} = -7.0 \times 10^{-7} g_o$
  $ø_{zy} = 45$ deg from z axis, $ø_{xy} = 46$ deg from x axis
  $R = 1.2 \times 10^{-6} g_o$
- Displacements based on lab centroid position

FURNACE ORIENTATION WITH RESIDUAL GRAVITY VECTOR

- Aisle intrusion is minimized by locating the furnace in a ceiling rack location, close to the truss; keeping Δx and Δz to a minimum

- Center of mass of ceiling rack location is 0.6m from center of lab; at ceiling location, MTC $ø_{zy} = 78$ deg, PMC $ø_{zy} = 46$ deg

- Gravity gradient resultant magnitude at ceiling location, under truss:
  MTC; $R = 1.9 \times 10^{-6} g_o$
  PMC; $R = 8.7 \times 10^{-7} g_o$

FURNACE ORIENTATION WITH RESIDUAL GRAVITY VECTOR

Conclusions

- Gravity gradient accelerations exceed CRD specified $1.6 \times 10^{-7} g_o$ off axis requirement
- Ceiling furnace rack locations under or near truss are preferred
- Resultant magnitude in the preferred location at PMC $< 10^{-6} g_o$
- At MTC, furnace "growth" axis is required to rotate 16 degrees out of alignment with the y axis of the rack; degree of aisle protrusion varies with furnace size
- Current rack envelope will accommodate 17deg of tilt in the lab radial plane (yz) and 18 deg of tilt in longitudinal plane(xy); furnace of 24 inch diameter and 54 inch length with container centroid at rack CM.
- TEA significantly affects the g-level and the resultant position with respect to the furnace, therefore aisle or adjacent rack intrusion cannot be ruled out
- Based on current data; recommend a rack replacement structure in furnace locations with adjustable linkages for attachment to standoff
- Furnace interfaces are significantly impacted by this requirement; requires further study

DR-2

Space Station Furnace Facility (SSFF)

Trade Study on

Ampoule Translation, Mounting, and Exchange

Conceptual Design Review
August 20-21, 1990
8:30 am - 4:30 pm
MSFC Building 4201
Room 437

INTRODUCTION

Teledyne Brown Engineering has begun work on the conceptual design of the Space Station Furnace Facility (SSFF). The SSFF is a multiuser facility capable of supporting a wide variety of experimentation in solidification physics and crystal growth. The preliminary definition of this facility has defined a variety of unique furnace modules which can be integrated into a common support system and structure for mission-particular experimentation. A contract for the conceptual design of this common support system and structure was awarded to TBE with Authority to Proceed given on June 2, 1989, and the contract was signed on August 31, 1989. The contract specified many trade studies to be performed in support of the conceptual design effort. On September 11, 1989, a Science Requirements Workshop was held to review the progress and priority of the work being performed with the science community. After a review of the tasks listed in the contract statement of work, the trade studies concerning the ampoule mounting, translation mechanisms, and sample exchange (paragraphs 5.5.3, 5.5.4, and 5.5.5, respectively) were considered by the science community to be of low priority and dependent on the designs of the unique furnace modules. Due to the immaturity of many of the furnace module designs, it was decided to minimize the effort for these analyses.

This report is a summary of the work performed under the following tasks:

5.5.3 <u>Hot Ampoule Exchange</u>

- Must sample cool before exchange
- Does sample cool in facility or in separate sample holder

5.5.4 <u>Ampoule Mounting</u>

- Position accuracy
- Support one or both ends of ampoule
- Is rotation capability required
- Thermocouple interface
- Universal holder versus several specialized

5.5.5 Translation Mechanism

- Ampoule loading
- Ampoule translation
- Sample differential translation (float zone)

To adequately complete these trade studies, specific information pertaining to furnace module designs is required. This level of detail may not be available until a furnace module nears a Critical Design Review completion. More detailed assessments of these issues should be performed as the furnace modules reach the preliminary and critical phases of design.

5.5.3 Hot Ampoule Exchange

A trade study on the benefits and merits of hot ampoule exchange was performed. The issue is whether the ampoule should be allowed to cool in the furnace core or removed hot and allowed to cool in a separate facility. Hot ampoule removal has the potential advantage of reducing sample processing time by the sum of the sample-furnace core cooldown time and the furnace core heatup time. The advantages and disadvantages of each technique are listed below.

Exchange Hot Ampoule

Advantages

- Processing time savings
- Furnace is not thermally cycled during each ampoule change

Disadvantages

- Burn hazard exists with manual exchange.
- Ampoule breakage toxicity hazard in cases where sample materials are toxic at high vapor pressures
- If an ampoule exchange carousel is used, the hot ampoule will radiate to other ampoules in the carousel
- A separate ampoule cooling canister may be necessary because of the above issue.
- Added experimental parameter due to the unknown cooling rate

Cool Ampoule Before Exchange

Advantages	Disadvantages
• Eliminates burn hazard. • Reduced risk of hot ampoule breakage	• Lost processing time

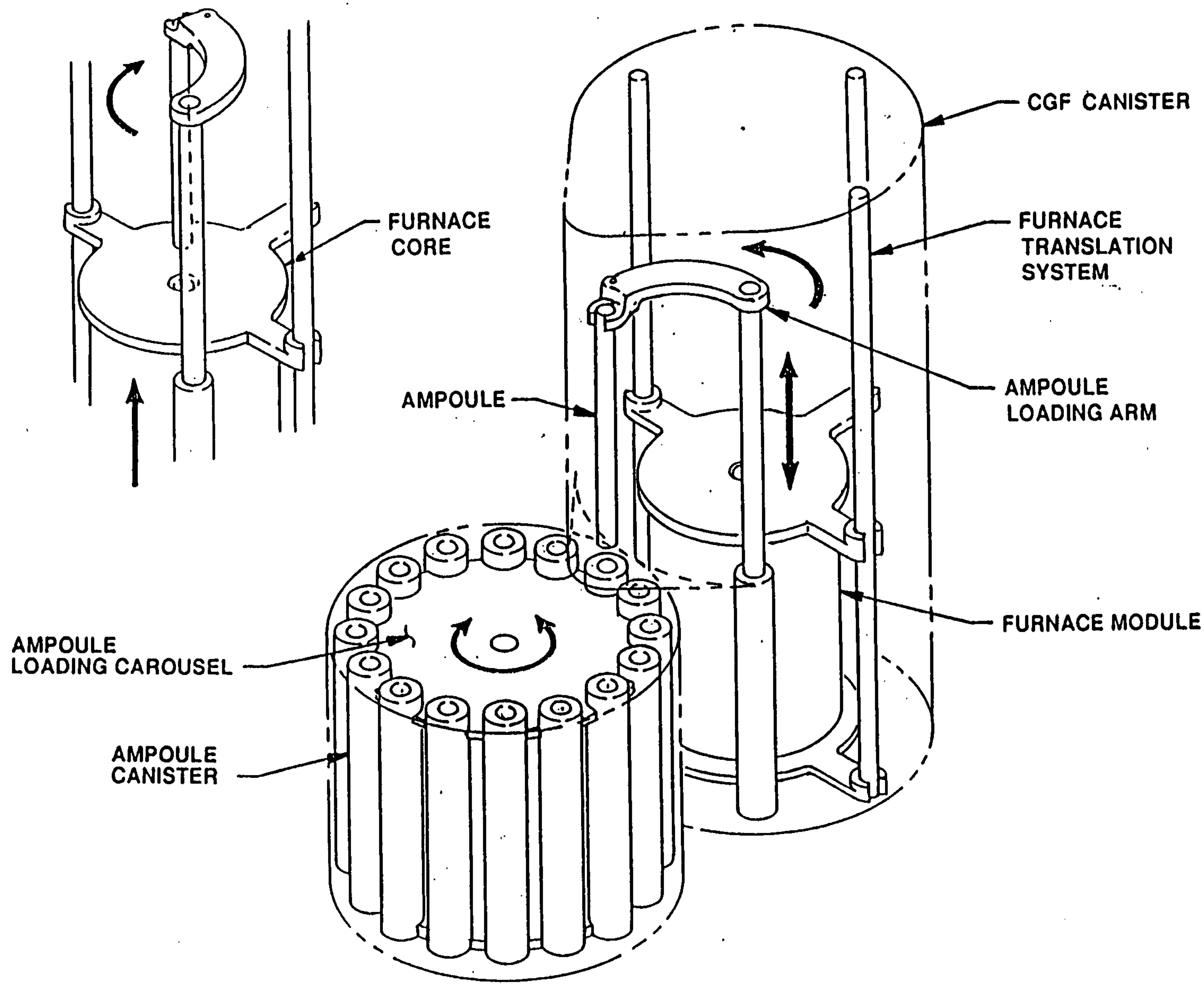
For the case of electronic materials processing (crystal growth), the sample exchange time compared to the sample processing time is small; therefore, it is felt that the small amount of time saved does not warrant the increased risks and complexity of hot ampoule exchange. However, in the case of metals and alloys experiments, the relatively short processing time (4 to 8 hours) may warrant the addition of a hot ampoule exchange system. In cases where higher cooling rates than allowed by the core heat loss rate are required by the experiment, a separate sample holder-container may be required. Cooling of the hot ampoule in a separate holder is investigated in the next study. A hot ampoule exchange design concept is also illustrated.

Cool in Furnace Core or Separate Holder

A trade study was performed to determine the benefits and difficulties involved in incorporating a separate sample container to allow out-of-furnace ampoule cooling. Such a system may be required on short-duration experiments or in cases where sample cooling rate may be an important experimental parameter. The advantages and disadvantages of each system are listed below.

Cool Sample in Separate Sample Container

Advantages	Disadvantages
• Offers an additional level of containment in case of an ampoule rupture during cooldown • Isolates the hot ampoule from the rest of the system and other ampoules.	• More complex system; greater cost • Difficult to adapt to existing furnace concepts such as CGF. The addition of a container to the existing design would lengthen the furnace by ~30 in. • Thermocouple/sensor outputs from the ampoule may be more difficult to configure.

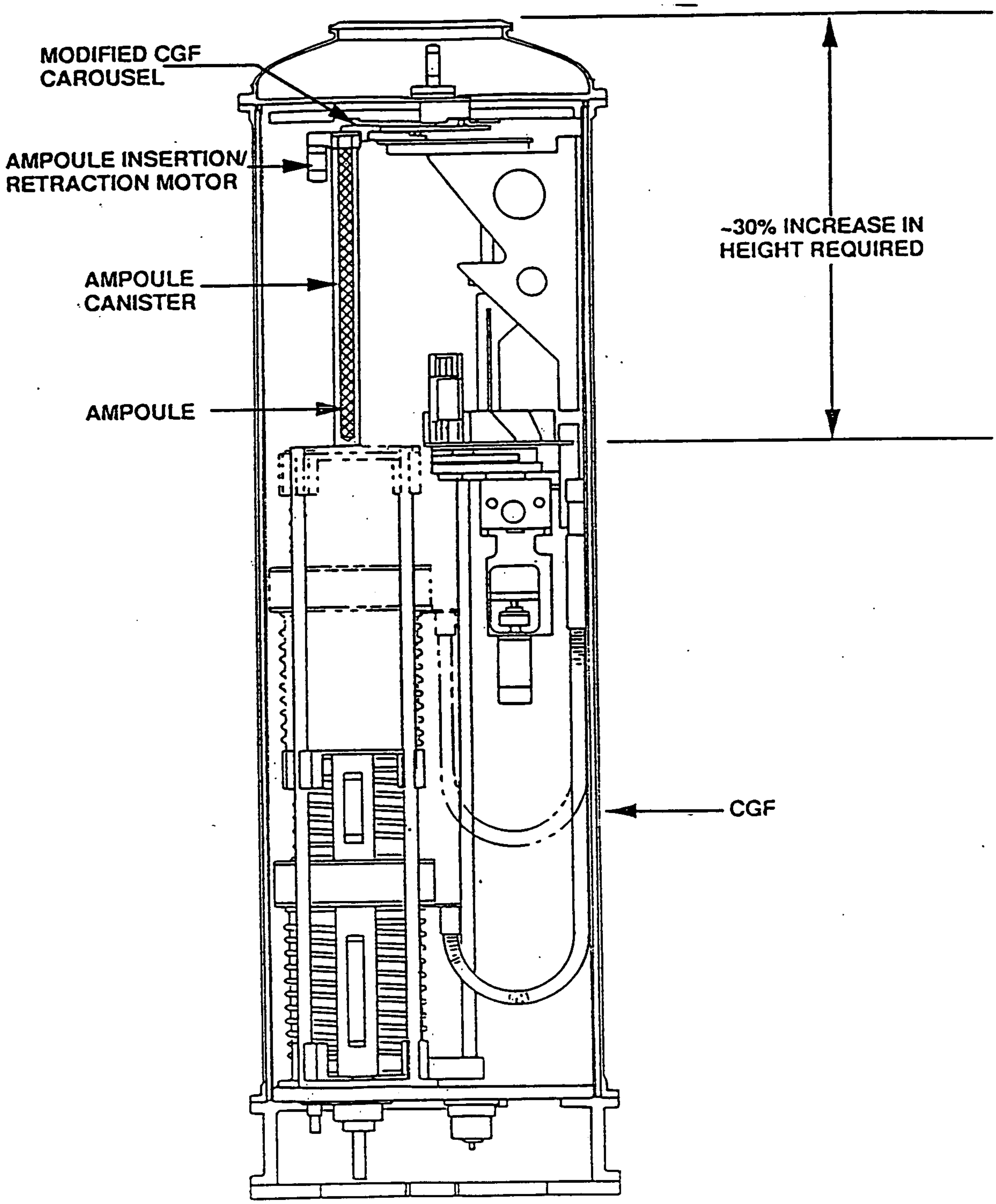


SAMPLE EXCHANGE CONCEPT

FIGURE I

FIGURE 2

CGF WITH HOT AMPOULE EXCHANGE CANNISTER



Cool Sample in Furnace Core

Advantages	Disadvantages
• Simplified design; lower cost • Lower rack space requirement	• Requires more processing time per sample • Fixed cooling rate

In cases where the experiment run time is short or where cooling rates may be higher than allowed by the furnace core, it may be necessary to incorporate a separate cooling canister. Ampoules could be loaded into the furnace core by an exchange arm and then unloaded back into a cooling canister. This concept is not easily adapted to any of the baseline furnace configurations and would require further study. A design concept for such a system is illustrated in Figure I. The addition of a load-unload ampoule container to the CGF carousel would require increasing the length of the furnace core and would place it outside the boundaries allowed by the rack space (Figure II).

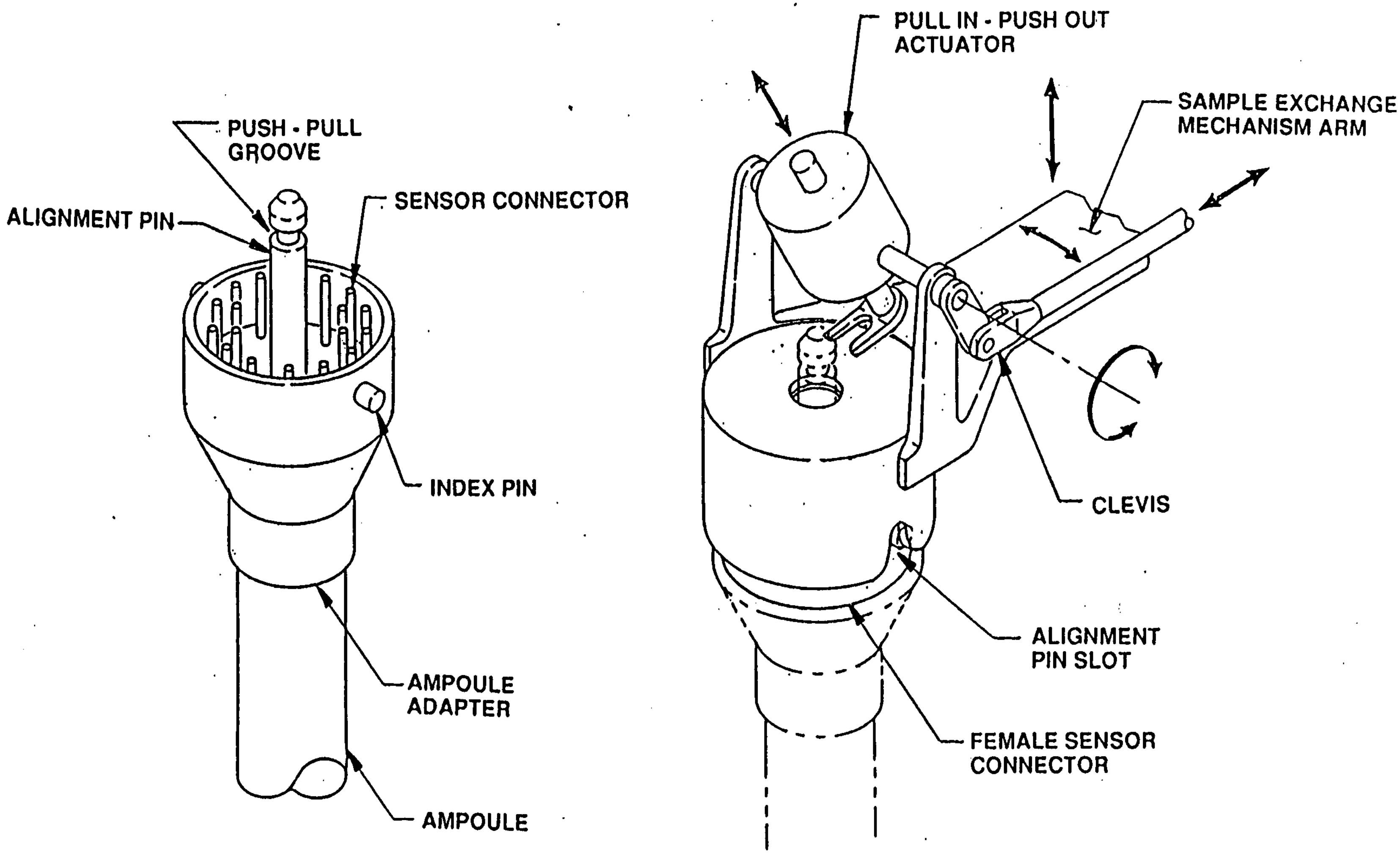
5.5.4 Ampoule Mounting-Universal Holder Versus Several Specialized Holders

The SSFF contract identifies the issue of utilizing a universal ampoule holder. The advantages and disadvantages of universal and specialized holders are listed below.

Universal Ampoule Holder

Advantages	Disadvantages
• Common holder design; possible cost savings • Easier to design into an automatic ampoule exchange system.	• Sensor output limited by common connection constraints • Material compatibility - difficult to design for when ampoule material may be an unknown • Limitation on thermocouple types

It would be advantageous to incorporate a universal ampoule holder or fixture into the furnace design. The design could be configured such that



AMPOULE ADAPTER CONCEPT

FIGURE III

each ampoule utilized an adapter flange which incorporated any of the ampoule unique features required. A design concept is illustrated in Figure III. This feature would make it much easier to incorporate an automated sample exchange system into the furnace design. However, because of the immaturity of the furnace module design concepts, it is recommended that this issue be set aside for further study.

Support One or Both Ends of Ampoule

A trade study was performed to determine the advantages of supporting the sample ampoule on both ends as opposed to one end only. The advantages and disadvantages of both configurations are listed below.

Support Ampoule on One End

Advantages

- Reduced heat loss out the end of the ampoule
- Furnace core may be closed on one end; reduced heat losses
- Reduced sample end effect on hot zone side
- Easier to accommodate ampoule thermal expansion

Disadvantages

- Less rigid ampoule mounting
- Ampoule alignment may be more difficult.

Support Ampoule on Both Ends

Advantages

- Increased rigidity
- During ground-based tests the lower support reduces any potential problems with ampoule creep and failure at elevated temperatures.
- Aids in ampoule alignment

Disadvantages

- Axial thermal expansion of the ampoule must be accommodated.
- Increased heat load-end effects
- A longer ampoule may be required.
- Requires the furnace core to be open at both ends
- To accommodate a multiple exchange system, the ampoule must be loaded through the furnace core on the lower support.

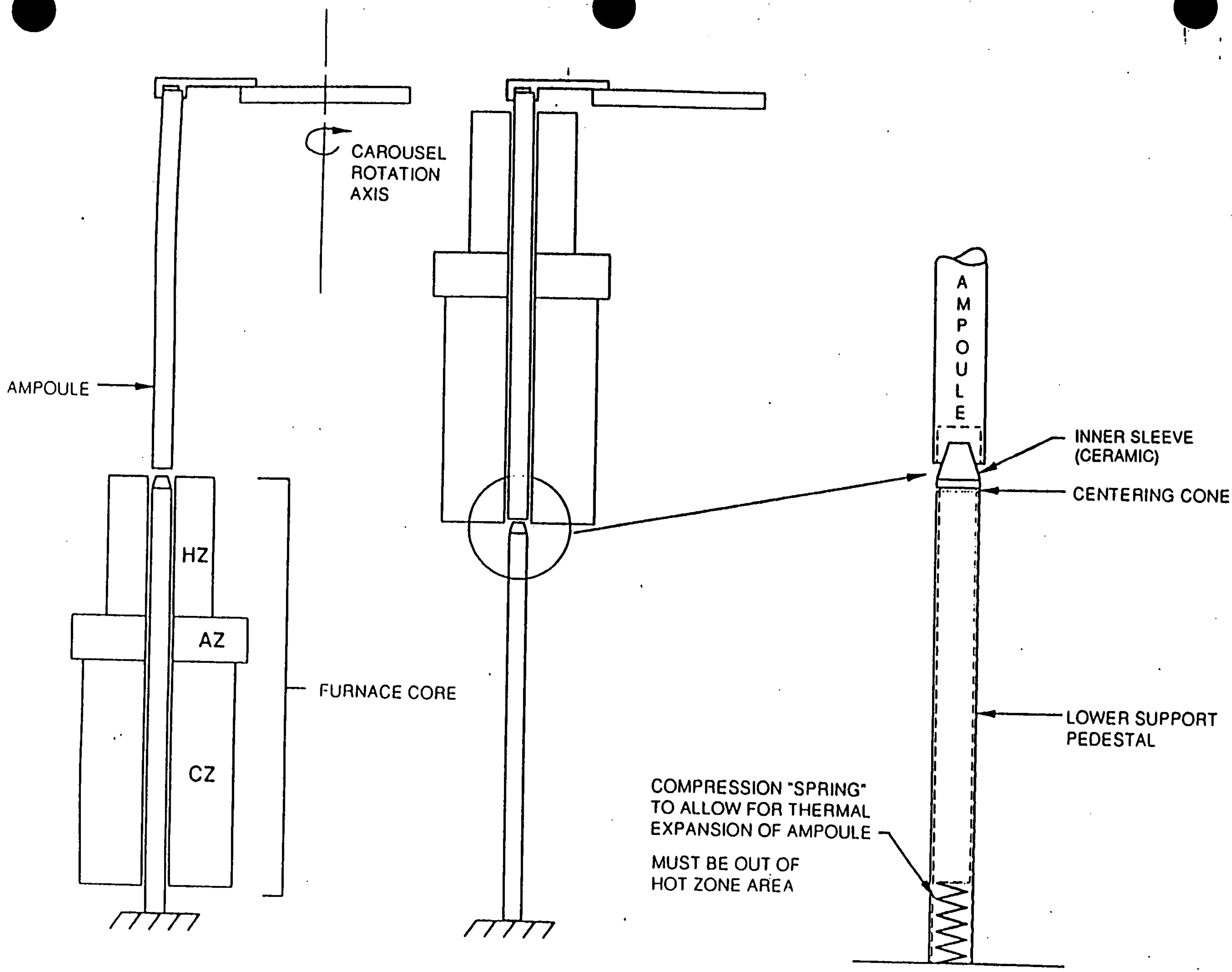


FIGURE IV. AMPOULE ATTACHMENTS TRADES

Sample support on one end only offers several advantages over a two-support system and is preferred. Figure IV shows a conceptual design for a two-support system. The greater simplicity of a single support negates any potential advantages of increased rigidity.

<u>Positioning Accuracy</u>

The contract specifies an ampoule position accuracy of ±0.1 cm with a resolution of 0.01 cm. It is not clear whether these numbers reflect axial and radial accuracy or concentricity with the furnace bore. Ampoule position and/or position measurement accuracy is a function of:

- The straightness of the ampoule
- Angular misalignment in the sample holder
- The positioning accuracy of the sample exchange mechanism
- The accuracy of positioning the sample in the ampoule
- The location of the ampoule position with respect to a reference point on the furnace core is controlled by the thermal expansion characteristics of the ampoule and the furnace structure.
- Position measurement accuracy with respect to a reference point on the furnace core is controlled by the resolution and accuracy of the position sensor - LVDT, Linear Potentiometer, optical encoder, etc.

Because of the equipment-specific nature of this issue, it is recommended that the issue be deferred to the furnace core manufacturer.

<u>Is Rotation Capability Required</u>

The issue of ampoule end rotation appears to be experiment specific. It is felt that the issue be deferred until experiment requirements are better developed.

<u>Sample Differential Translation (Float Zone)</u>

No float zone furnaces are identified in the candidate baseline.

<u>Thermocouple Interface</u>

This study addresses the location of the ampoule thermocouple lead wire termination point and how the TC lead wire connection is made.

Considerations involved with this issue are:

- Automated or manual sample exchange
- Accommodation of a variety of thermocouple types
- Lead wire length
- Ampoule mounting.

The feature of automatic or manual exchange is required by the contract. If the ampoule is designed to be loaded and unloaded automatically by an exchange mechanism, then each ampoule must have a common end configuration or adapter to allow it to be coupled to the exchange arm. The thermocouple connection point should be integral with the ampoule coupler. The TC-sensor connection plug should be designed to allow for both automated coupling and manual coupling. The contract guidelines and assumptions statement require that the design allow for six to eight thermocouples per sample. Utilizing only one thermocouple type would require 16 thermocouple connection points per ampoule. If the ampoule exchange arm connector is designed to allow for 3 thermocouple types, 48 thermocouple connection points are required.

The connection point might either be a pin-type connector or a series of radial "pads" around the exchange mechanism adapter on the end of the ampoule. Due to the equipment-specific nature of this study, it is recommended that the final decision be deferred to the furnace core manufacturer.

5.5.5 Translation Mechanism

Common Translation System

The furnace translation system may be either furnace-core unique or common with the rack. The advantages and disadvantages of each system are listed below.

Common Translation Mechanism

Advantages

- Lower cost; common components
- The drive components may be better isolated from the furnace environment.
- The translation rates required may be accommodated by a common system.

Disadvantages

- It may be very difficult to design a translation system to accommodate the wide variety of furnace configurations, shapes, and lengths.
- The furnace core design would be driven by the translation rack space requirements.
- For the case of furnace translation it will be more difficult to maintain atmospheric integrity of the furnace core.
(Bellows may be required.)
- This configuration requires a more modular furnace design and possibly more setup time.

Translation Mechanism Integral with Furnace Core

Advantages

- The entire furnace apparatus is contained in a single enclosure as in CGF, AADSF, and MASA.
- Reduced setup time upon experiment changeout
- Similar to existing designs
- The furnace core design is not driven by the need to couple to a common translation rack.

Disadvantages

- Potentially higher cost

The use of a common translation system has many potential problems which may be difficult to solve. Therefore, it is recommended that the use of a common translation system be abandoned in favor of the use of common translation system components such as motors and drive screws. The translation system for each furnace core could be designed from a catalogue of

common flight-certified components. This inventory of flight-certified components would be developed and maintained by the SSFF Project.

Ampoule Translation Versus Furnace Translation

Directional solidification requires controlled relative motion between the furnace and the sample during processing. The goal is to minimize acceleration imposed on the sample by the translation mechanism or changes in translation velocity. The SSFF contract requires a maximum g level of 10^{-4}. To achieve the required relative motion, either the furnace or ampoule must be translated. The advantages and disadvantages of each technique are listed below.

Furnace Translation

Advantages

- Minimize the acceleration imposed on the sample by the translation mechanism - the sample sees no accelerations from speed changes (other than drive train vibration).
- Easier to accommodate a multiple sample exchange mechanism. The exchange system must be integral with the translation system in a sample translation configuration.

Disadvantages

- Requires more rack space; two complete furnace core volumes are required.
- Furnace translation requires a higher torque capacity drive system.

Sample Translation

Advantages

- Cables associated with power, cooling, sensors, etc., are not required to move.
- It is possibly easier to have a common translation system with this configuration.

Disadvantages

- More exposure to drive system vibration and acceleration

Furnace translation is preferred because of the g-level requirement of the contract. Furnace translation reduces the magnitude of acceleration disturbances imposed on the sample by drive system noise and translation rate changes.

Ampoule Loading

The contract states that the furnace be capable of both manual and automated ampoule loading. This requirement is closely tied with the requirements of section 5.5.3 in the contract and cannot be treated as an independent issue. Several ampoule loading schemes can be envisioned.

- Direct loading by hand into the ampoule-holding fixture
- Automatic loading by a carousel
- Automatic loading by an exchange arm from an ampoule carousel canister (Figure I)
- Automatic loading by a fully articulated robotic system

Design issues:

- Does the loading mechanism interfere with the ampoule being manually loaded?
- Will the automatic loading device be capable of meeting the ampoule alignment requirements or will a separate alignment mechanism be required?
- Does the design allow for hot ampoule exchange?
- How are thermocouple lead wires and sensor wires routed through the exchange mechanism?
- Does the loading mechanism allow for variation in ampoule lengths?
- How will the exchange mechanism - ampoule holder be protected from heat conduction up the ampoule?
- If the ampoule is loaded from a separate container, does the ampoule storage container share a common vacuum and backfill system with the furnace?
- Are motion points or mechanical joints in the exchange mechanism designed to be self-locking or do they require active control to maintain a given position?

DR-2

Space Station Furnace Facility (SSFF)

Trade Study on

Magnetic Suppression System Assessment

Conceptual Design Review
August 20-21, 1990
8:30 am - 4:30 pm
MSFC Building 4201
Room 437

OBJECTIVE

The objective of this study is to determine the technical feasibility and resource impacts of a magnetic suppression system on the SSFF. A concept for this system is provided as a basis for the feasibility assessment.

The approach to performing this study involved a consideration of different types of magnet systems which have been classified into three categories: 1) superconducting magnet systems, 2) normal electromagnet systems and 3) permanent magnet systems. Concepts from each category are discussed in the following paragraphs.

ASSUMPTIONS USED IN THE STUDY

To establish the ground rules and to serve as a point of departure, the following assumptions were used in these analyses. The results and conclusions drawn at the end of this report are based on this list.

- The allowable Space Station Rack Load is 700 kilograms at launch. This places an upper bound on the mass of any piece of equipment which cannot be assembled on orbit.

- The generated DC magnetic field shall not exceed 170 dB picotesla above 1 picotesla at the payload envelope.
  No specific requirement for DC magnetic field emissions from payloads in the Space Station Freedom Laboratory Module could be found at the time of this study. This requirement was taken from Space Shuttle Payload interface Control Drawing, ICD-2-19001, Paragraph 10.7.3.2a. This limits the allowable magnetic flux emitted from the Magnetic Suppression Subsystem to 0.3 gauss.

- The desired magnetic field is 2000 gauss in a direction parallel to the growth axis of the specimen.

- The magnetic field is desired over the length of the hot zone

Additional assumptions used in the studies of the different types of magnets will be given in the discussions that follow.

MAGNETIC FIELD SHIELD DESIGN

Due to the requirements limiting magnetic field emissions from payloads on the Space Station Freedom, it is necessary that a magnetic field shield be used in conjunction with the magnet in the magnetic suppression concept since the magnitude of the flux desired (2000 gausses) is far greater than the anticipated limiting value on emissions. For direct current (dc) fields, a magnetic field shield provides a low reluctance path for the magnetic flux being shielded. The attenuation or shielding efficiency of a magnetic shield is the ratio of the measured field before shielding to that measured after shielding. In general, magnetic shields that are cylindrical provide greater attenuation than shapes with square corners. For cylindrical shields, the attenuation is inversely proportional to the inside diameter of the shield, thus the larger the volume of the shielding chamber the lower its attenuation for a given thickness of shielding material.

In magnetic field shield construction, it is desirable to select a material with a high permeability for high attenuation and a high saturation level. Above saturation, shielding effectiveness drops exponentially. A typical material used in the construction of magnetic field shields is mu-metal. Mu-metal is an alloy of Nickel, Copper, Chromium and Iron. It has a maximum permeability of 100,000 and a saturation induction of 6500 gausses. In this study, mu-metal is considered for the magnetic field shield construction as well as two alloys which are commercially available and will be referred to here as "Alloy 1" and "Alloy 2". The properties of interest of these alloys are presented in Table 1. "Alloy 1" has a very high permeability for maximum attenuation, but a low saturation level. "Alloy 2" has a relatively low permeability, but a high saturation level. The B/H curves for the three magnetic shielding materials considered in this study are presented in Figures 1, 2, and 3.

Using the given properties and B/H curves, the performance of each material was evaluated in this study. Figure 4 shows a plot of the level of magnetic flux emitted by a magnetic shield as a function of the shield thickness for the three alloys under consideration. The magnetic flux emitted by the shield is the flux level after shielding. This plot was produced for an interference field of 2000 gausses and a shield inside diameter of 44 centimeters. From this plot, at an

emitted flux level of 0.3 gauss, "Alloy 1" requires the smallest shield thickness which is mainly due to the fact that it has the highest permeability. "Alloy 1" is selected here as the material for the shield construction and for this alloy the level of magnetic flux after shielding is plotted as a function of shield thickness for various shield inside diameters in Figure 5. This plot was developed for an interference field of 2000 gausses. Thus, this figure can be used to determine the required shield thickness for various shield sizes and a desired emitted flux level. Figure 6 is a plot of the resulting shield mass versus the shield thickness for various shield inside diameters. This plot was developed for an interference field of 2000 gausses also. By using Figure 5 to determine the required shield thickness for a desired emitted flux, Figure 6 can the be used to determine the resulting shield mass. Figure 7 is a plot of the minimum shield thickness required to avoid material saturation as a function of the shield inside diameter for various source or interference flux values. This minimum shield thickness is the minimum thickness required to prevent saturation of the shield, after which the emitted magnetic flux will increase exponentially.

Table 1 - Magnetic Field Shield Material Properties

	Mu-Metal	"Alloy 1"	"Alloy 2"
Specific Gravity	8.5	8.74	7.86
Saturation Induction, Gauss	6,500	7,500	21,000
Maximum Permeability	100,000	450,000	4,000
Coercive Force, Oe	0.05	0.015	1.0
Curie Temperature, °C	400	454	770

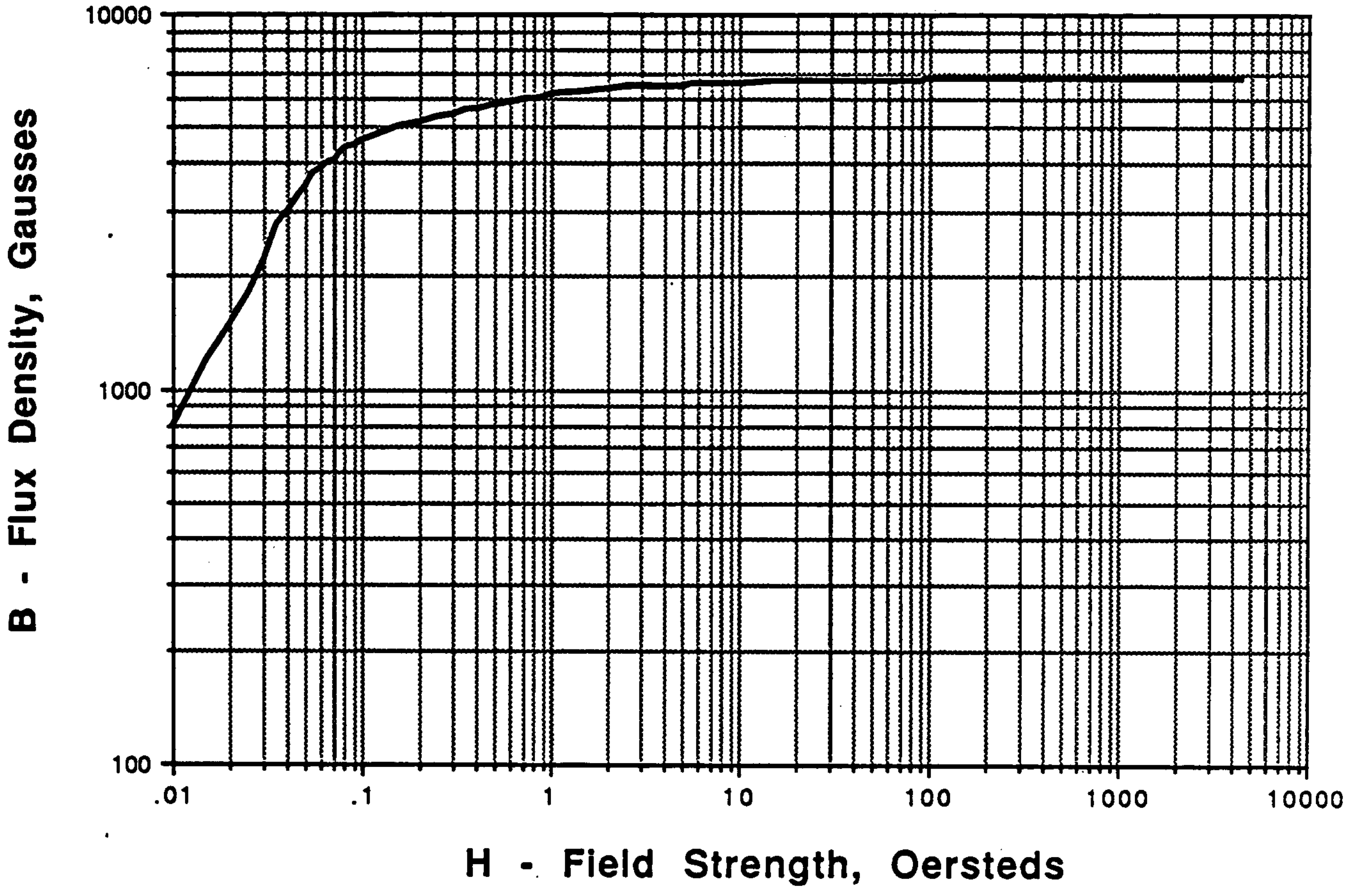


Figure 1 - B/H Curve For Mu-Metal

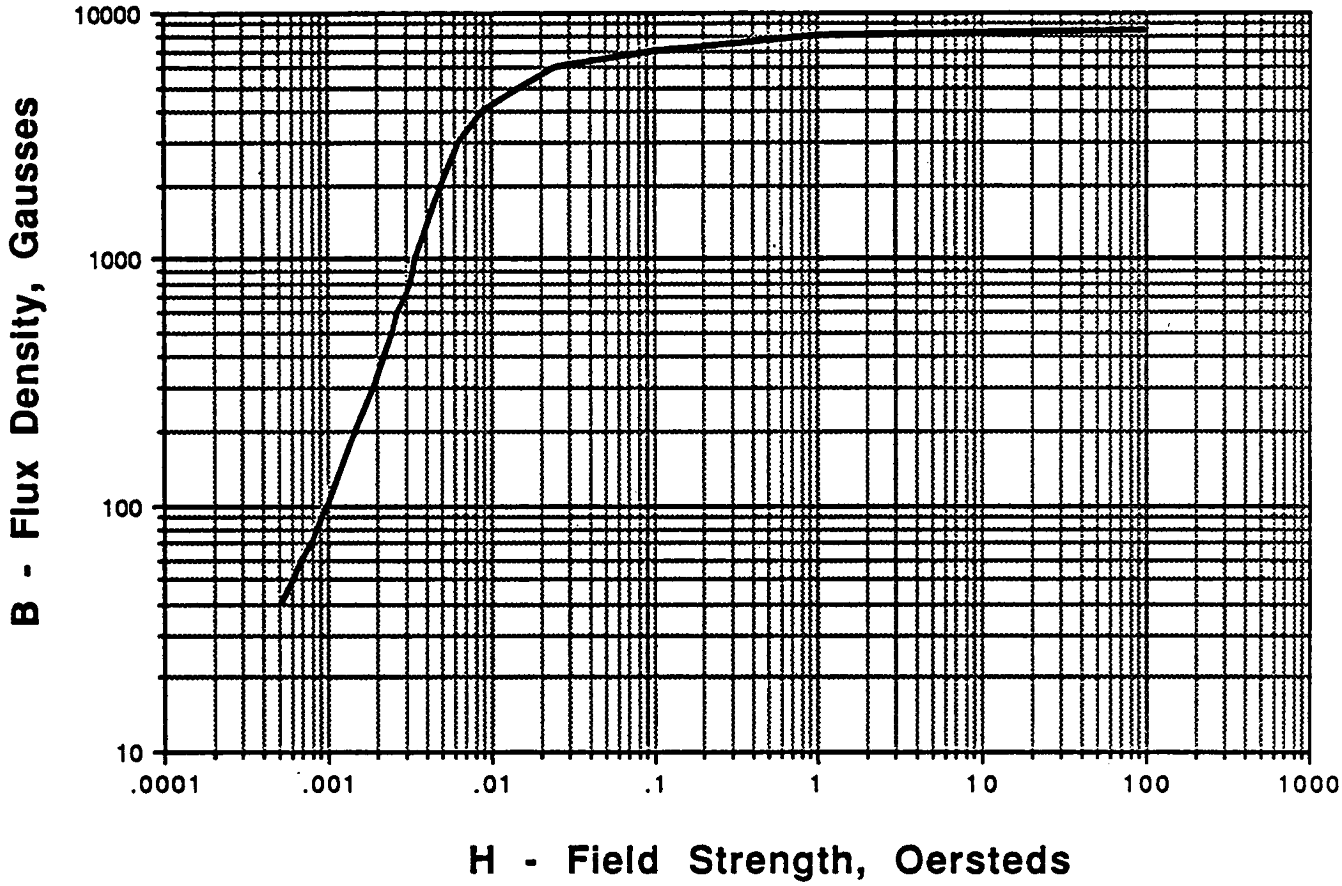


Figure 2 - B/H Curve For "Alloy 1"

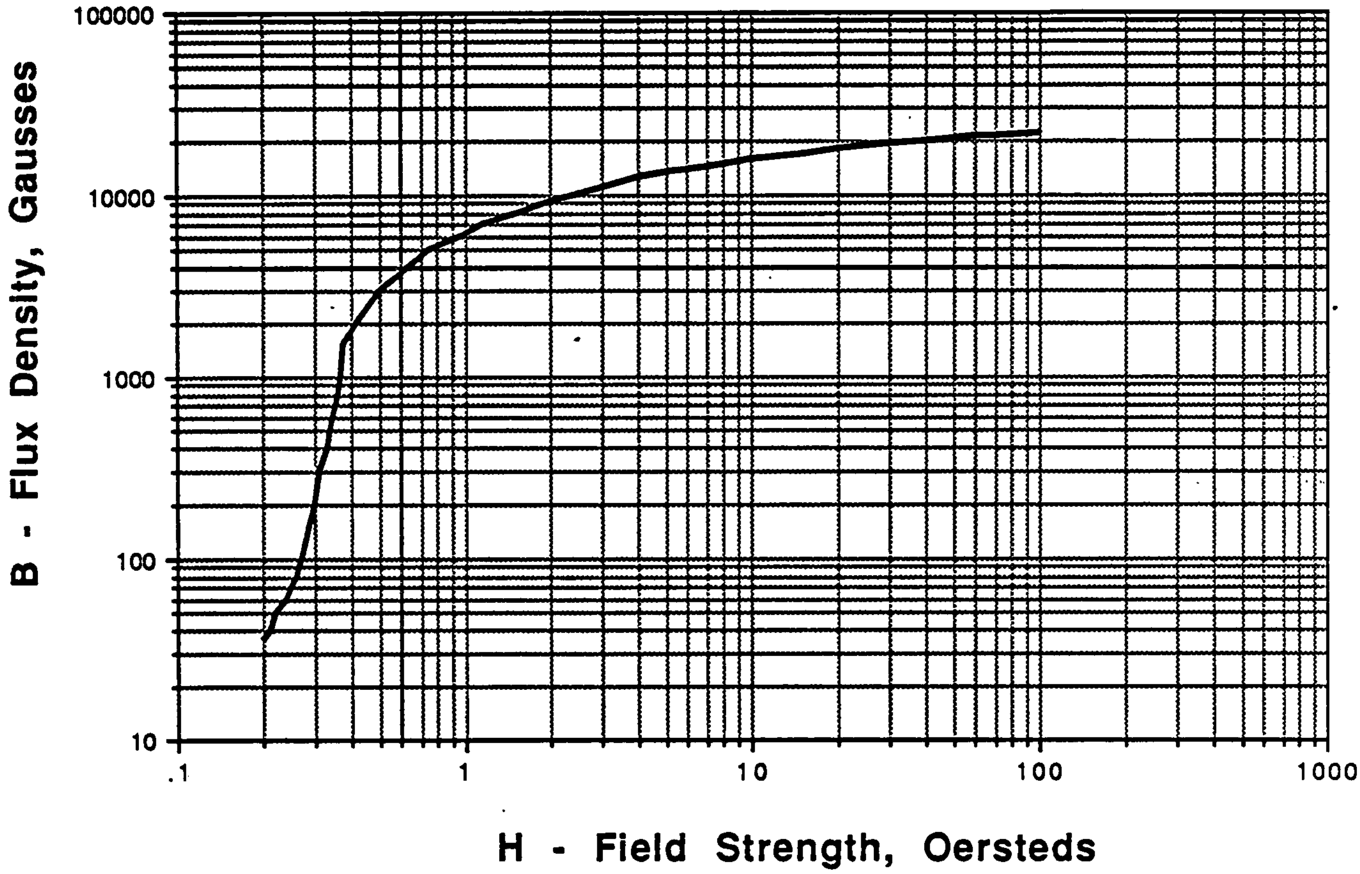


Figure 3 - B/H Curve For "Alloy 2"

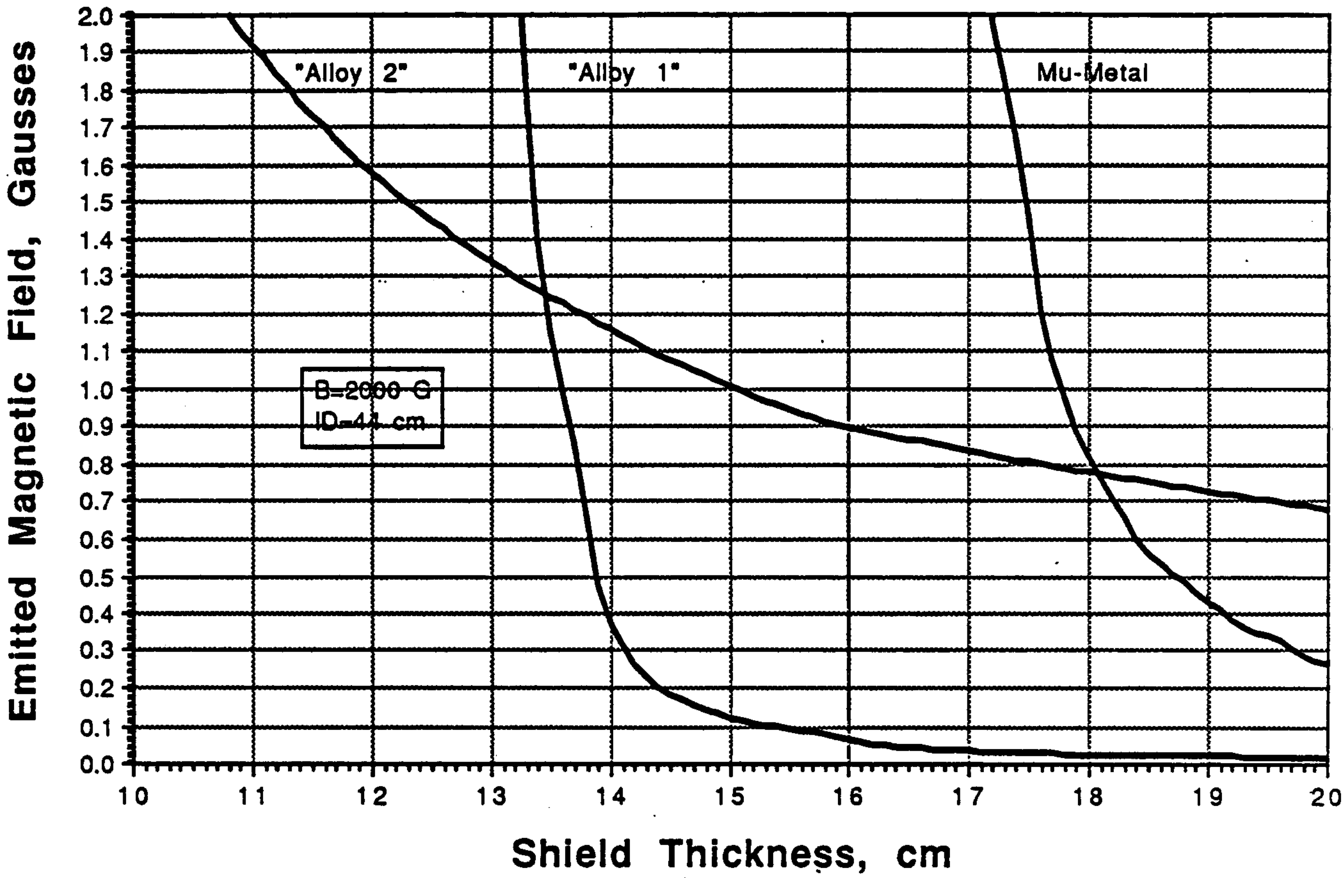


Figure 4 - Plot Of Emitted Magnetic Field vs Shield Thickness For Shield Materials

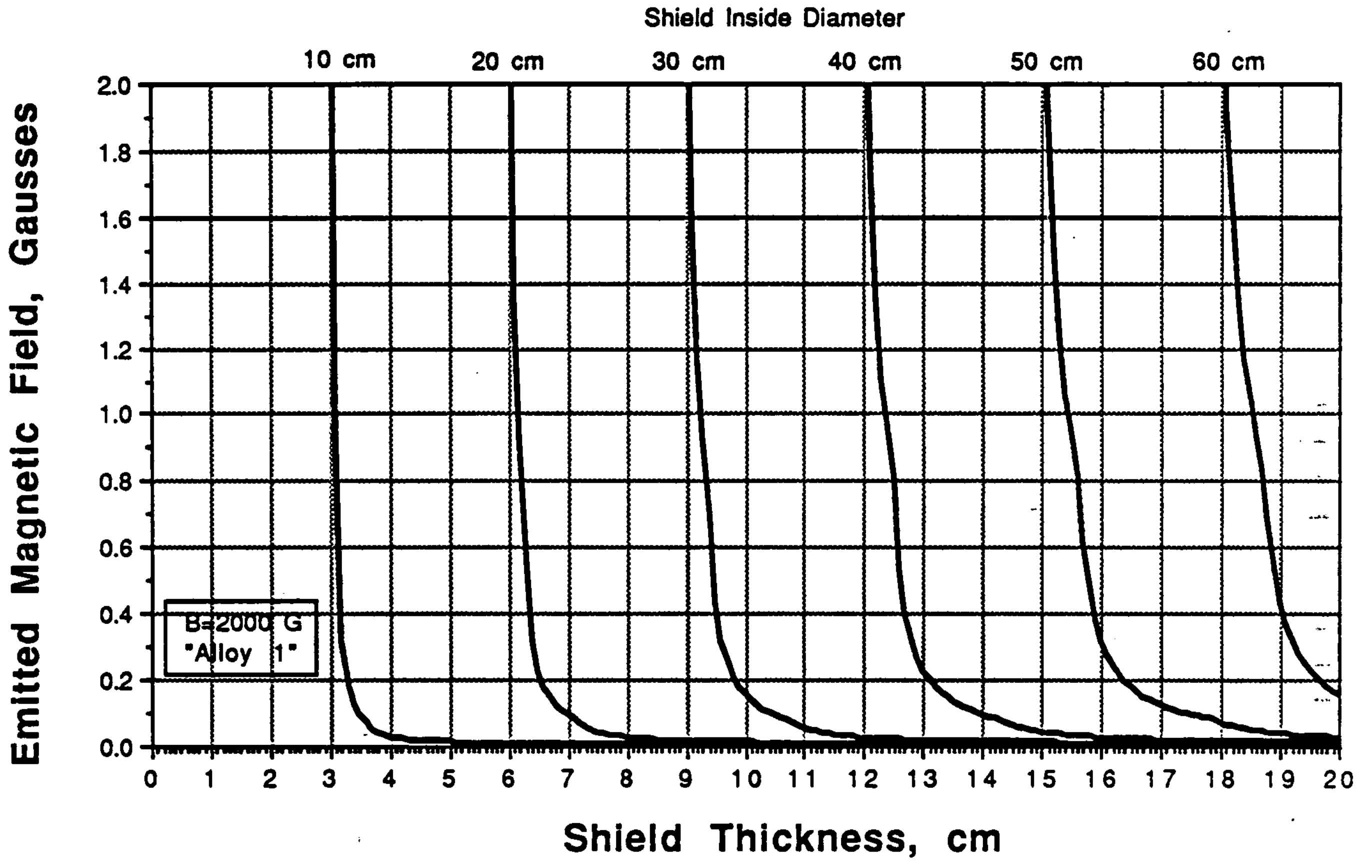


Figure 5 - Plot Of Emitted Magnetic Field vs Shield Thickness ("Alloy 1")

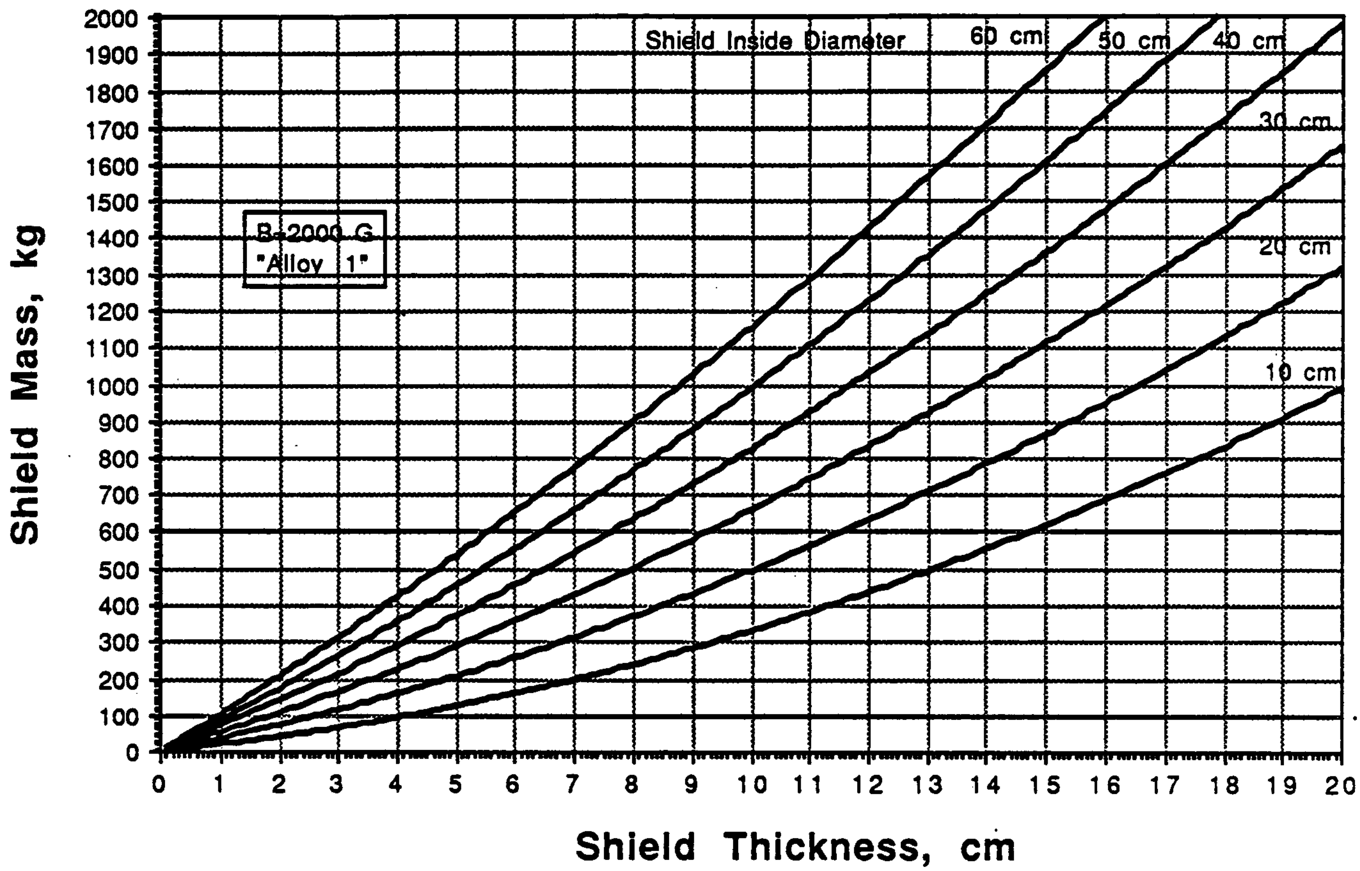


Figure 6 - Plot Of Shield Mass vs Shield Thickness
("Alloy 1")

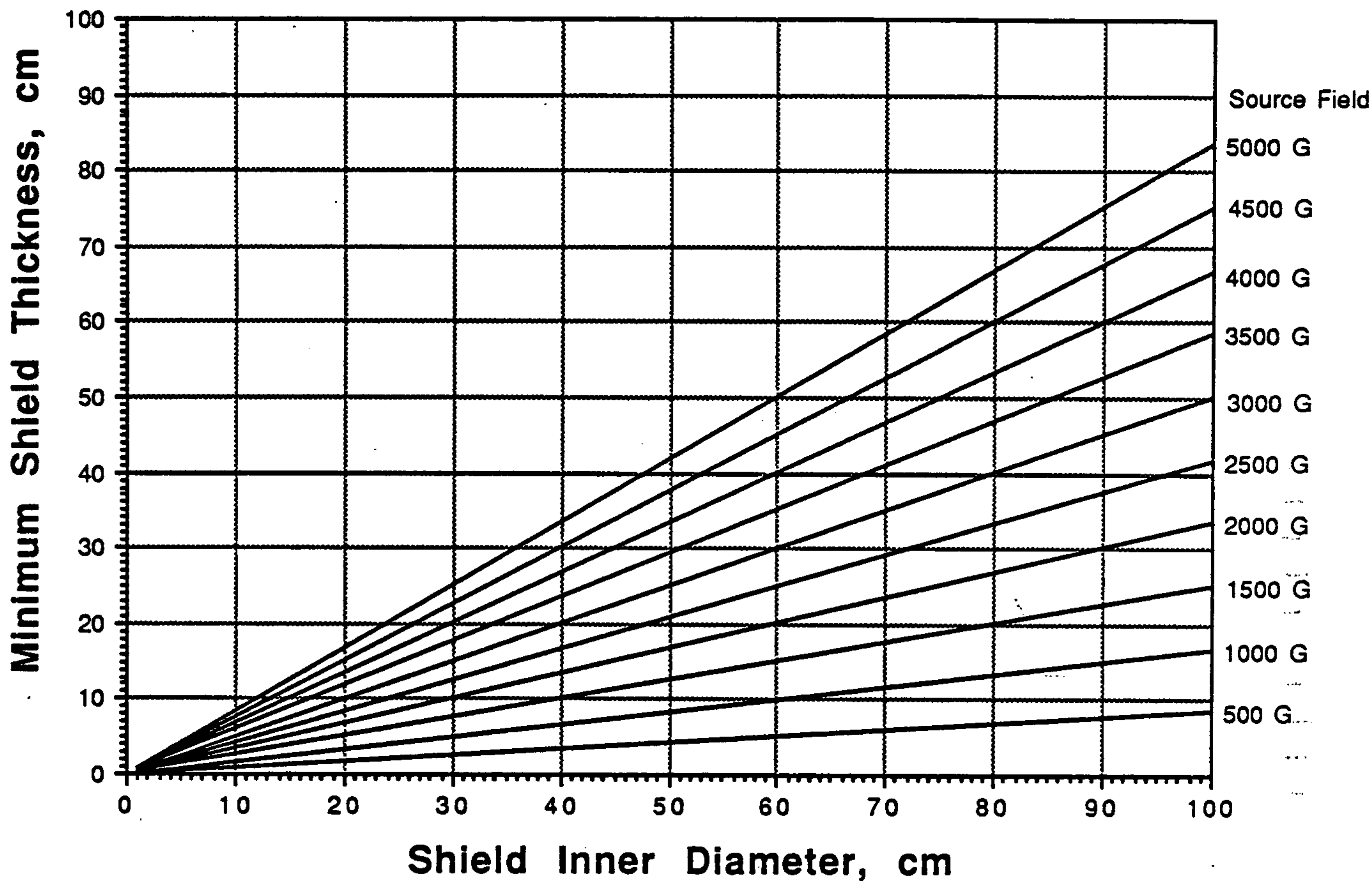


Figure 7 - Plot Of Minimum Shield Thickness vs Inner Diameter ("Alloy 1")

SUPERCONDUCTING MAGNET SYSTEM CONCEPT

The merits of a using a superconducting magnet in the magnetic suppression system were considered in this study. It was determined that this type of magnet is not feasible at this time. The following is a summary of the assessment performed pertaining to this approach.

Conceptual Design

The superconducting magnet concept consists of three major assemblies, namely: the magnet and dewar, a closed cycle refrigerator and a power supply and control system.

The dewar has a clearance bore to permit the insertion of a crystal growing furnace module in its center. The dewar is equipped with fixtures to allow liquid helium and liquid nitrogen filling and venting. The dewar is also plumbed to allow connections to the closed cycle refrigerator. The magnet resides in a helium filled chamber which is maintained at 4.2 ^{O}K. In order to minimize helium consumption, the magnet chamber is surrounded by a radiation shield which is stored in liquid nitrogen and maintained at 20 ^{O}K. The outer surface of the dewar is maintained at room temperature. The dewar is instrumented with temperature sensors attached to the radiation shields and the magnet chamber. The U. S. standard Space Station Freedom rack will not accommodate the dewar; therefore, non-rack provisions must be made for it.

The magnet is a solenoid typically wound using conductors made of many filaments of superconductor material embedded in a copper matrix and twisted along its axis to decrease its diamagnetism. Insulation is provided by the insulation on the wire and by epoxy between each turn. The magnet is wound on a cylinder made of aluminum, brass or stainless steel.

The closed cycle refrigerator is used to maintain the radiation shields at 20 °K. It is attached to the top of the dewar by an armored cable. Terrestrial refrigerators are air-cooled. The refrigerator can be installed in a U. S. standard Space Station rack.

The magnet controls and instrumentation and power supplies can be installed into a standard U. S. rack.

Resource Requirements

The resource requirements presented are based on an actual terrestrial state-of-the-art superconducting magnet system utilizing a 5 K Gauss magnet. This system is manufactured by American Magnetics, Inc., a leading supplier of superconducting magnet systems and cryogenic accessories.

Mass and Volume Requirements

The inner bore of the dewar is 86 centimeters in diameter and the outside diameter is 163 centimeters. This inner bore dimension is expected to be large enough to accommodate the furnace modules in the SSFF study and allow room for additional insulation around the furnace module if necessary to decrease nitrogen and helium consumption by the magnet system. The dewar and magnet have a combined mass of 13200 kilograms. The closed cycle refrigerator has a width of 50 centimeters, a depth of 50 centimeters, a height of 43 centimeters and has a mass of 309 kilograms. The power supply and control system will have a mass of 657 kilograms and occupy a volume 56 centimeters wide, 89 centimeters deep and 107 centimeters high.

Power Requirements

The magnet must be energized prior to operation. The electrical power to energize the magnet is 1.6 kW. The time to energize the magnet is 30 minutes. After the magnet is energized it can be switched to a persistent mode where there is no power requirement. If the cryogenic fluids are reused, a closed cycle refrigerator requiring 1.5 kW continuously will be required. It is estimated that the power supply and control system will consume about 500 watts continuously.

Consumables

As heat is absorbed by the system, the liquid nitrogen and liquid helium in the system will vaporize and must be replaced periodically. The liquid nitrogen

consumption rate is approximately 4 liters per hour and the liquid helium consumption rate is approximately 200 milliliters per hour.

Venting

The helium and nitrogen gases from the magnet system must be vented or captured and stored for reuse. Either way, provisions must be made for rapid venting in the case of loss of cooling or some other catastrophic event. The magnet system will have a large amount of stored energy. Superconducting magnets experience a phenomena called "quenching". This is an unpredictable process where resistance returns to the magnet. This generates a large amount of heat which vaporizes large quantities of the cryogens.

Critical Issues

There are several areas requiring technology development in the use of a superconducting magnet system in space. These include:

Magnetic field shielding techniques

The magnetic fields developed must be shielded to avoid causing interference with other payloads and experiments. Magnetic fields are known to cause problems in equipment such as computers.

Cryogenic fluid control systems

Research and development must be performed in the area of cryogenic fluid storage in low gravity as well as in the area of cryogenic fluid flow devices to insure safe and reliable designs for use in space.

Safety

Safety techniques must be developed to reduce the chances of catastrophic failure of the systems.

PERMANENT MAGNET SYSTEM CONCEPT

Additionally, this study considered a permanent magnet system, but the weight and volume limitations constrain this system such that 2000 gauss cannot be provided. The following describes the concept used as a basis for this assessment.

Conceptual Design

Concepts involving the use of permanent magnets have been examined in this study. From literature on the subject and discussions with manufacturers of permanent magnets, it was concluded that the only way that a permanent magnet could be used in this application is by placing the magnet in a magnetic circuit. To use a permanent magnet alone with no circuit, to produce a 2000 gauss magnetic field at the required distance from the magnet surface, would require a very massive magnet and it did not appear to be a viable option. In this concept, the magnetic circuit considered is shown in Figure 8. In this circuit the magnet has a rectangular cross section and pole pieces of mild steel are used to direct the flux to the working gap where the furnace module is placed. The length of the gap must be sufficient to accommodate the overall length of the furnace module. In this concept, a furnace module with an outside diameter of 20 centimeters and an overall length of 50 centimeters is considered.

Even though permanent magnets seem physically simple, their operational complexities are evident when the factors that affect the performance of magnets are considered. There are few sources of practical, published information to provide the necessary expertise in magnetics. Some of the factors that affect the performance of permanent magnets are: the magnet material, magnet size, magnet shape, the location of magnet in the circuit, level of magnetization, location of the poles, magnetization before or after placement in circuit, material of which poles are made, the shape of the pole pieces, environmental conditions such as temperature, shock and demagnetizing fields, the material of which the pert on which the magnet acts is made, and the size of the part on which the magnet acts.

In this study different magnet materials were considered and calculations were performed using Alnico V and a rare earth magnet NdFe24. From the study of

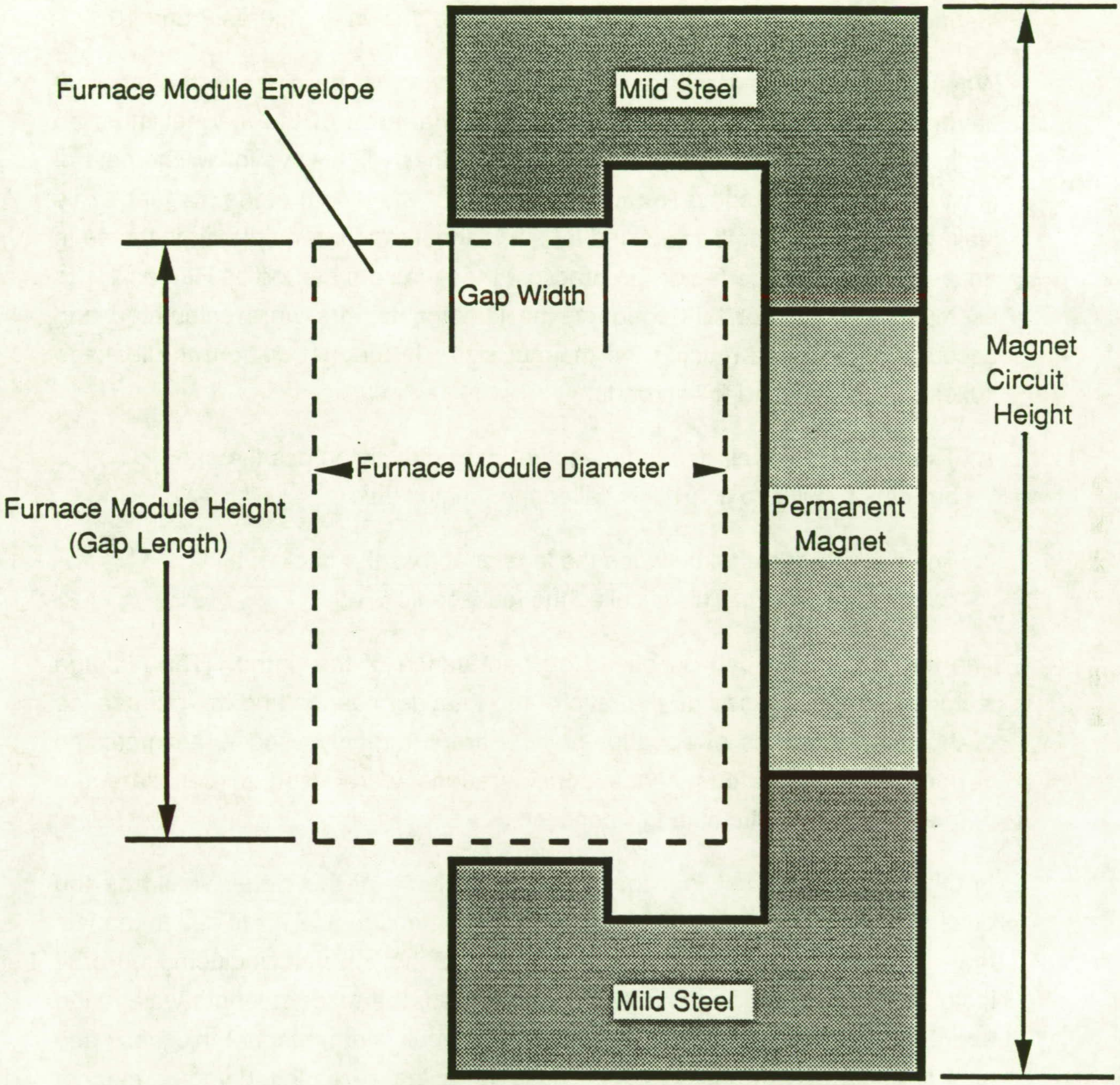


Figure 8 - Permanent Magnet Concept

magnetics, it is evident that the B/H ratio is the key to how a basic magnet will perform in the circuit. The demagnetization/energy product curves for the magnet materials considered in this concept are shown in Figures 9 and 10.

When using a permanent magnet consideration must be given to the flux that never reaches the air gap. The cross-sectional area of the magnet must be sufficiently sized to allow for flux losses. Flux lines will always follow the path of least reluctance and some flux will "jump across" the length of the magnet. This leakage flux must also be supplied by the magnet, and it requires an increase in area by some leakage factor. In practice, these factors can be as little as 1.1 to as much as 50. For this concept, the leakage factors were calculated and accounted for in determining the magnet size. In magnet design, the leakage fluxes can be reduced to two parts.

1. The flux near the air gap that does not pass directly across the gap but runs parallel to it. This is called the fringing flux.

2. The flux that radiates between the legs or across the back of all parts of the circuit. This is called the leakage flux.

The leakage factor can be based on permeance of the paths. The leakage factor can be expressed as the ratio of the total permeance and the permeance of the gap. A series of equations which are commonly used to estimate the permeances for various space considerations were used to calculate the permeances of the circuit in this concept.

In this study it was felt that the mass and volume of the circuit would be the drivers of the feasibility of the use of a permanent magnet. This is due to the fact that it must be shielded during all phases of the mission, including on-orbit installation. For the magnetic circuit considered, the magnet length was varied and the resulting circuit mass, circuit height, circuit width, magnet thickness and total permeance were calculated. These variables were plotted versus magnet length for both magnet materials considered for a flux of 2000 gausses in the air gap. For Alnico V, Figure 11 is a plot of circuit mass versus magnet , Figure 12 is a plot of circuit length versus magnet length, Figure 13 is a plot of circuit width versus magnet length, Figure 14 is a plot of magnet thickness versus magnet length and Figure 15 is a plot of total permeance versus magnet length. Each of

these plots include curves for various gap lengths. These same plots are presented for NdFe24 in Figures 16 - 20. From Figure 11, the circuit mass has a minimum value at a certain magnet length. This happens because the total permeance is a function in part of the magnet area to length ratio. Thus the minimum values for each gap length represent sort of an optimum value. Comparing Figure 11 and Figure 16 shows that the NdFe24 magnet has its optimum values at lower magnet lengths than the Alnico V. This is consistent with the fact that NdFe24 has a greater maximum energy product that the Alnico V, meaning it is generally a "stronger" magnetic material. NdFe24 is thus the material of choice since we want to minimize mass and volume. To accommodate a furnace module 50 centimeters in height, a gap length of at least 50 centimeters is required. Figure 11 shows that for a 50 centimeter gap length, the circuit has its minimum mass of approximately 4000 kilograms at a magnet length of 45 centimeters. Using Figure 12, for a magnet length of 45 centimeters, the circuit length is approximately 260 centimeters and from Figure 13 the circuit width is approximately 220 centimeters. The circuit width sets the inside diameter of the shield to be used. From Figure 6 for a shield inside diameter of 220 centimeters the shield thickness will be greater than 80 centimeters (by extrapolation) which will result in a shield mass of perhaps 10000 kilograms. Thus to use a permanent magnet, the gap size in the circuit considered must be very small to become feasible from a mass and volume standpoint.

Resource Requirements

The resource requirements for the concept utilizing a permanent magnet were based on accommodating a furnace module with an outside diameter of 20 centimeters and an overall length of 50 centimeters. The requirements were estimated for a system with an emitted magnetic flux of 1.0 gauss as well as for 0.3 gauss.

Mass and Volume Requirements

The overall mass of this concept will be in excess of 10000 kilograms. The height of the system will be approximately 450 centimeters with a width of 400 centimeters.

Power Requirements

There is no power requirement associated with this concept.

Thermal Requirements

There is no thermal requirement associated with this concept.

Data Requirements

The data requirements for this concept are well within the scope of the SSFF capabilities.

Venting Requirements

No venting requirement has been identified for this concept

Consumables

No consumables requirement has been identified for this concept.

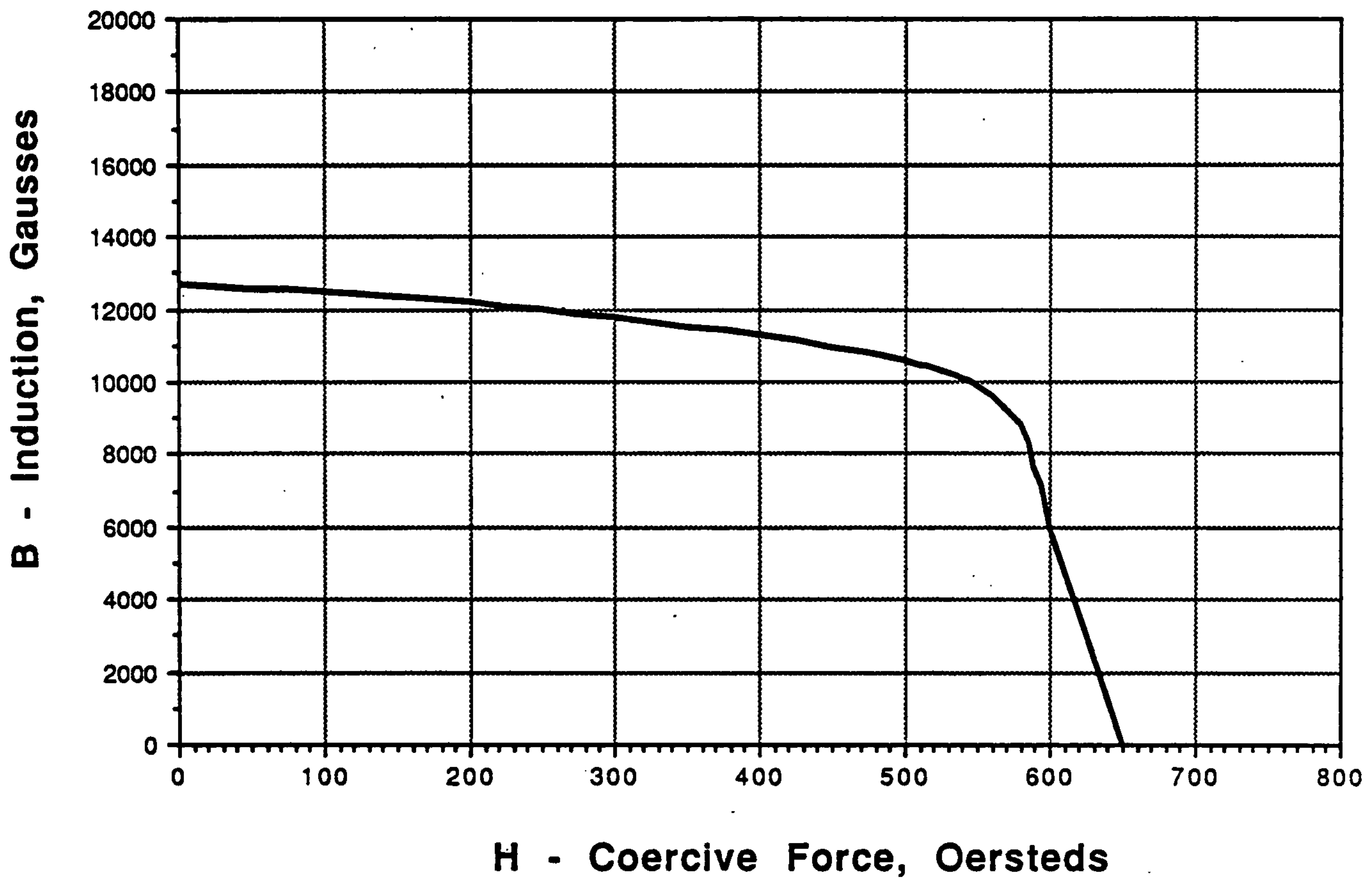


Figure 9 - Demagnetization Curve For Alnico V

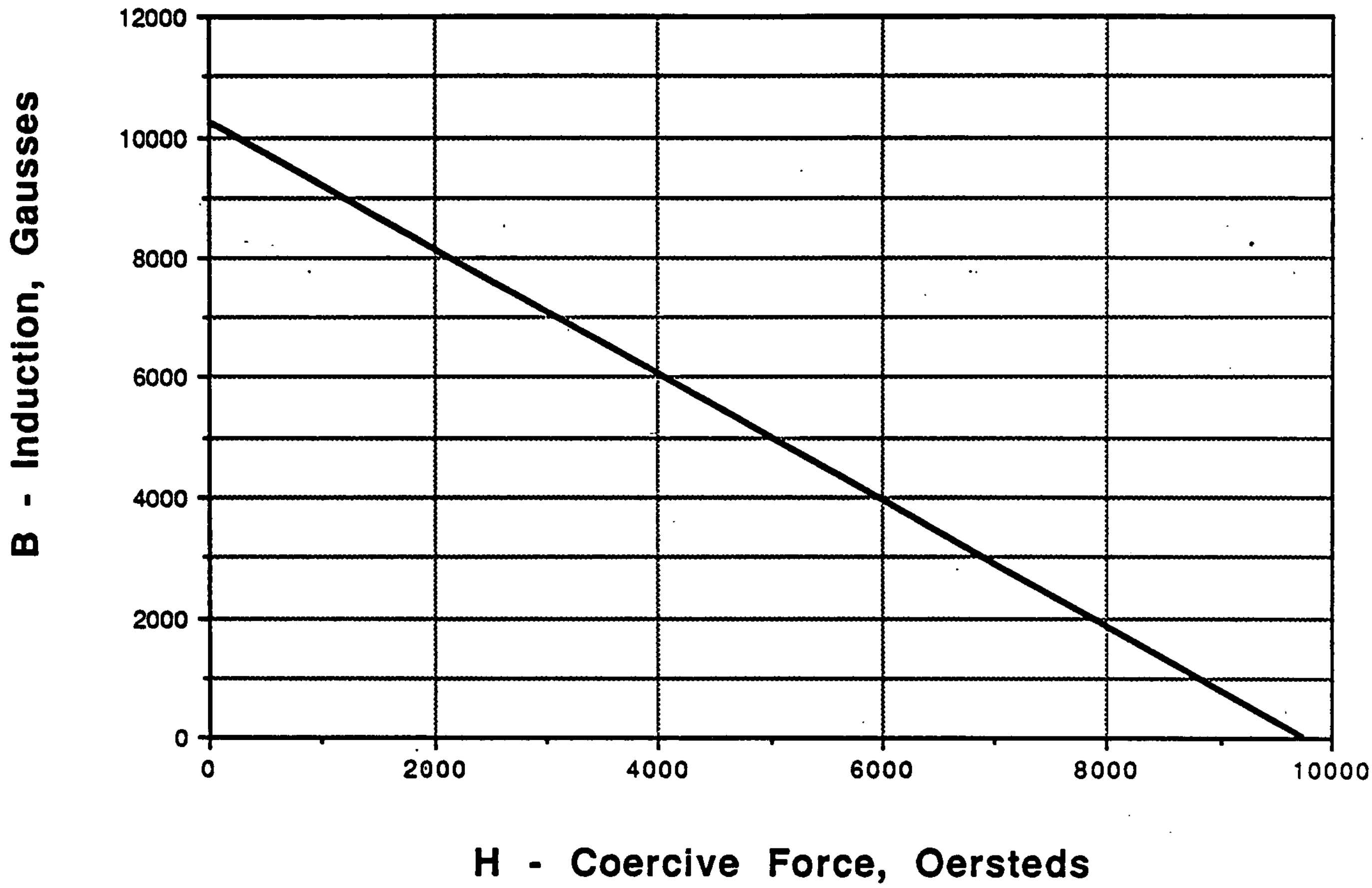


Figure 10 - Demagnetization Curve For NdFe24

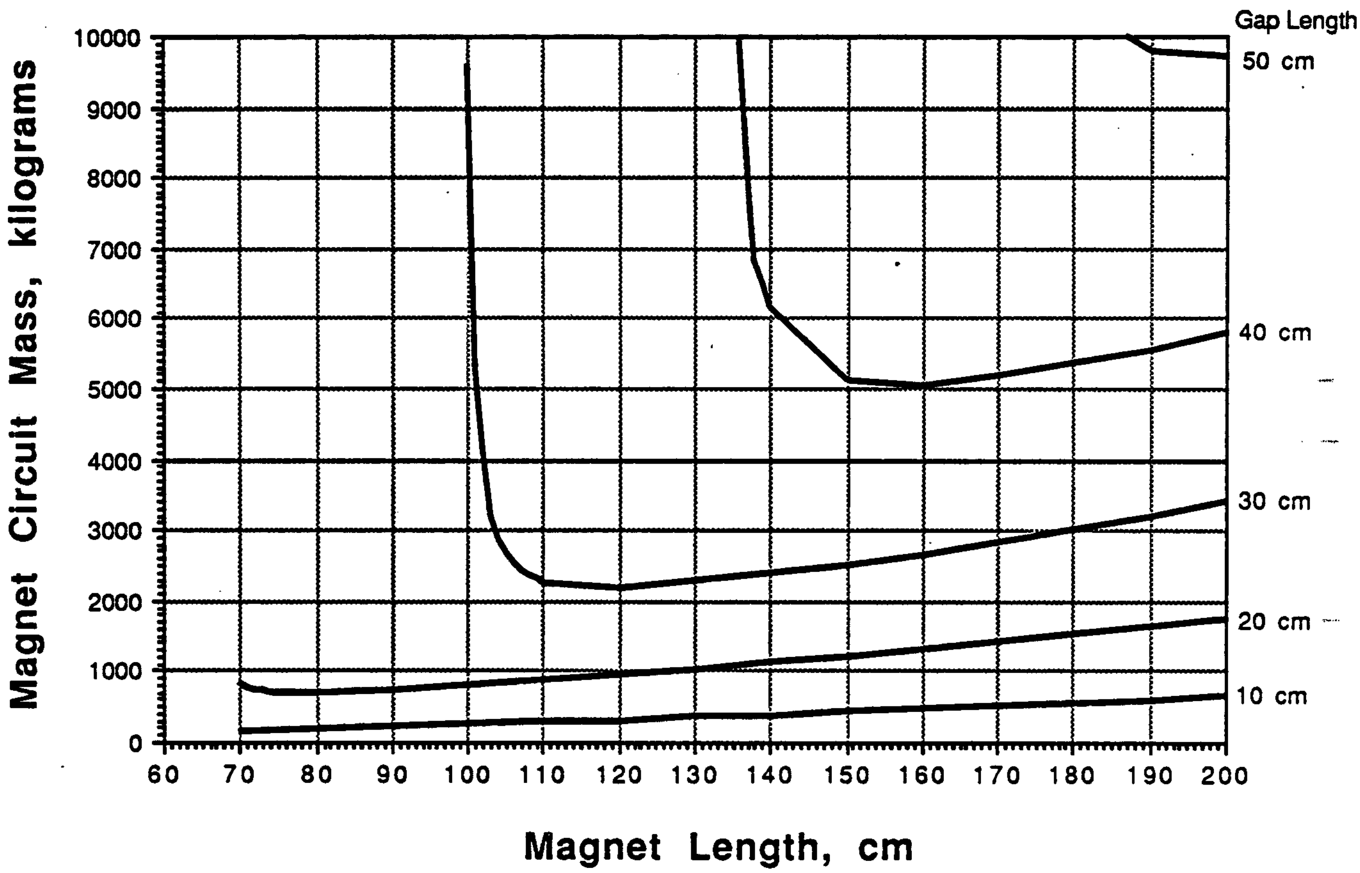


Figure 11 - Plot Of Circuit Mass vs Magnet Length For Alnico V

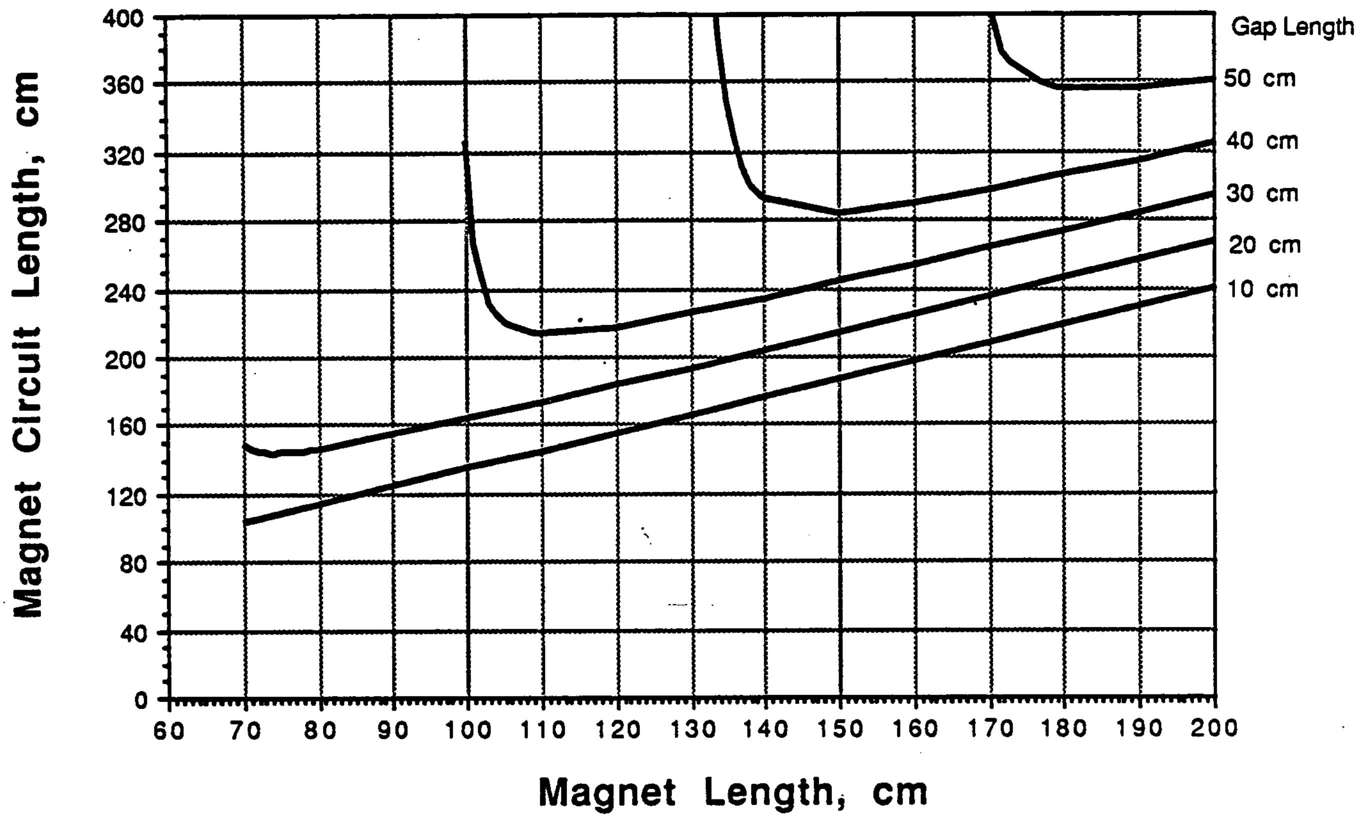


Figure 12 - Plot Of Circuit Length vs Magnet Length For Alnico V

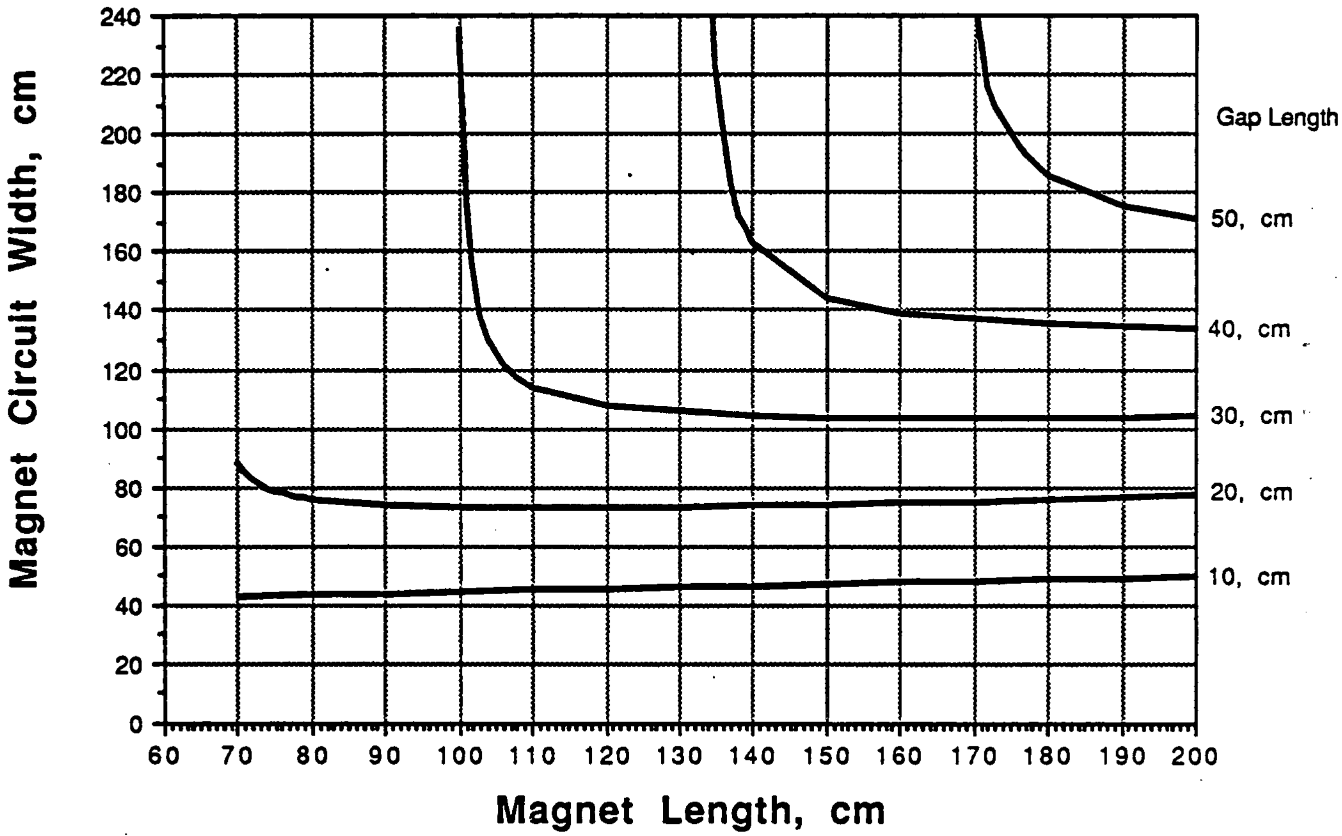


Figure 13 - Plot Of Circuit Width vs Magnet Length For Alnico V

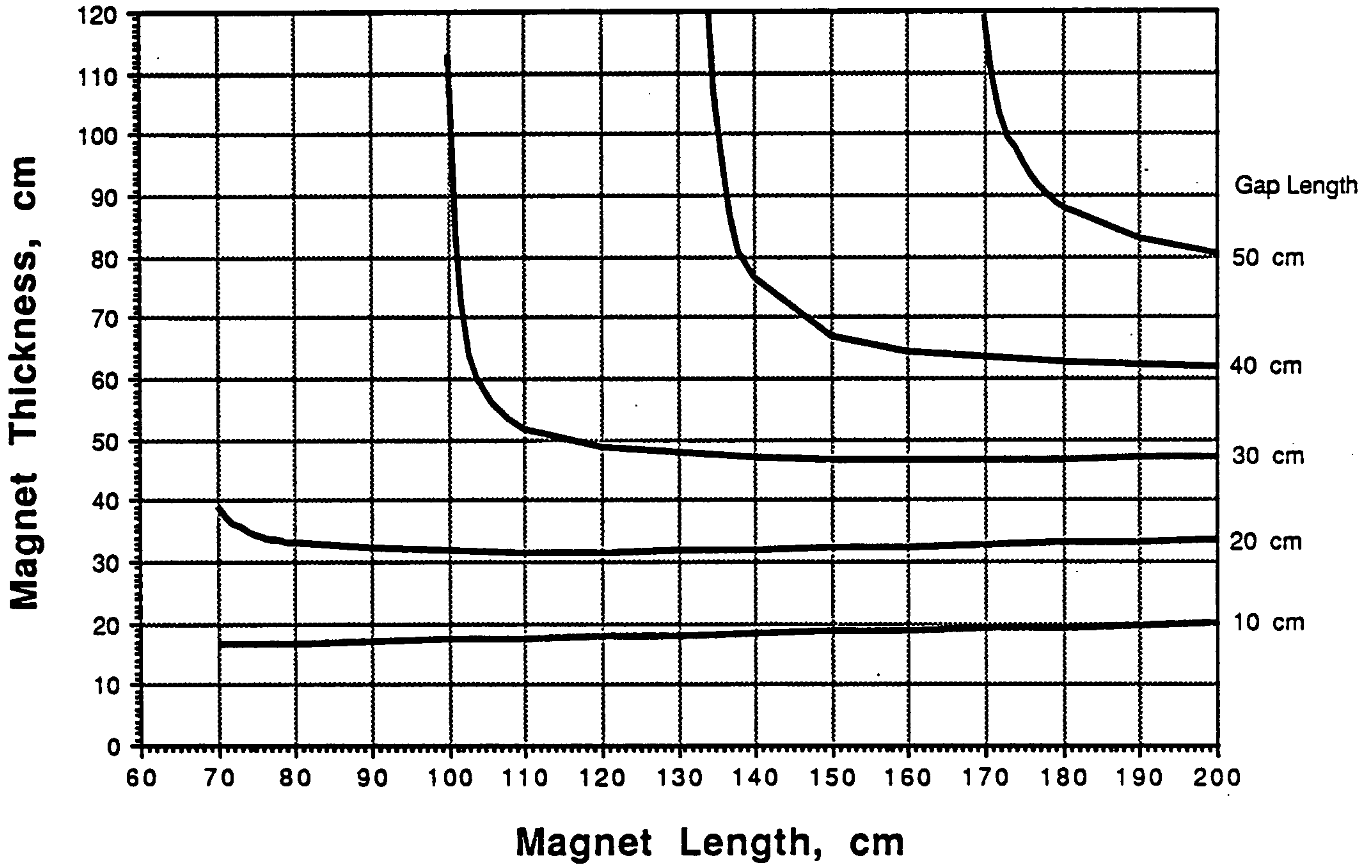


Figure 14 - Plot Of Magnet Thickness vs Magnet Length For AlnicoV

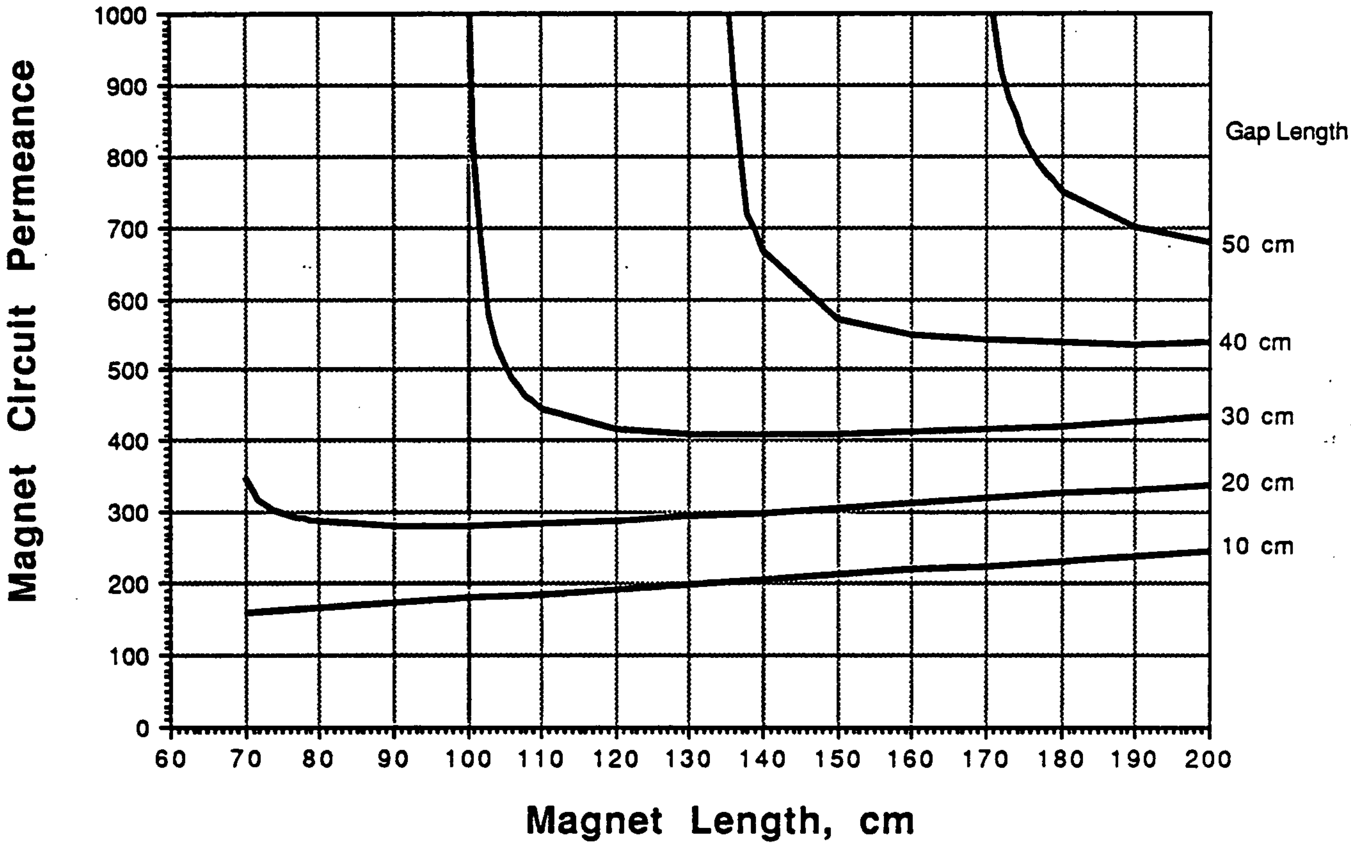


Figure 15 - Plot Of Circuit Permeance vs Magnet Length For AlnicoV

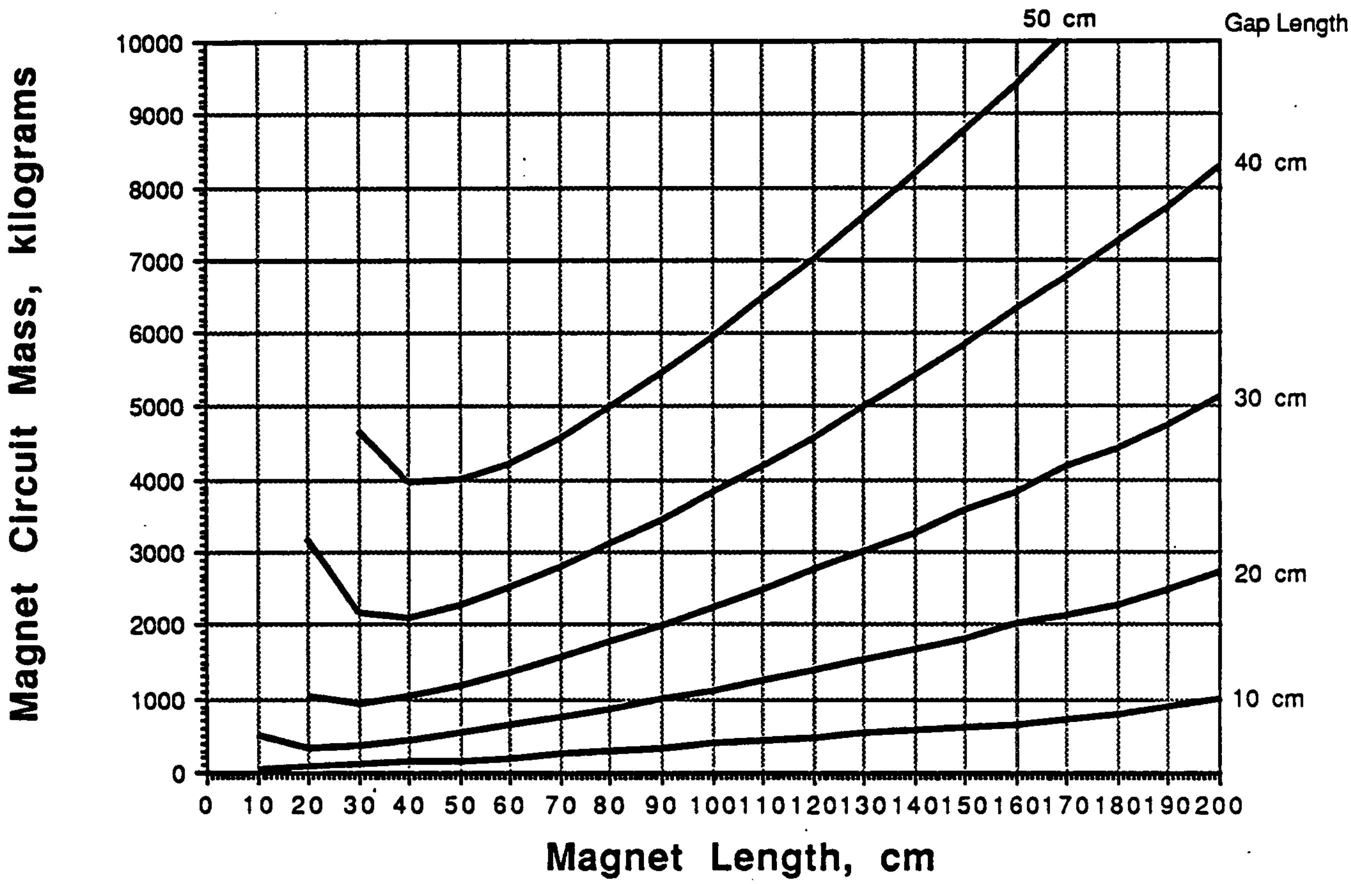


Figure 16 - Plot Of Circuit Mass vs Magnet Length For NdFe24

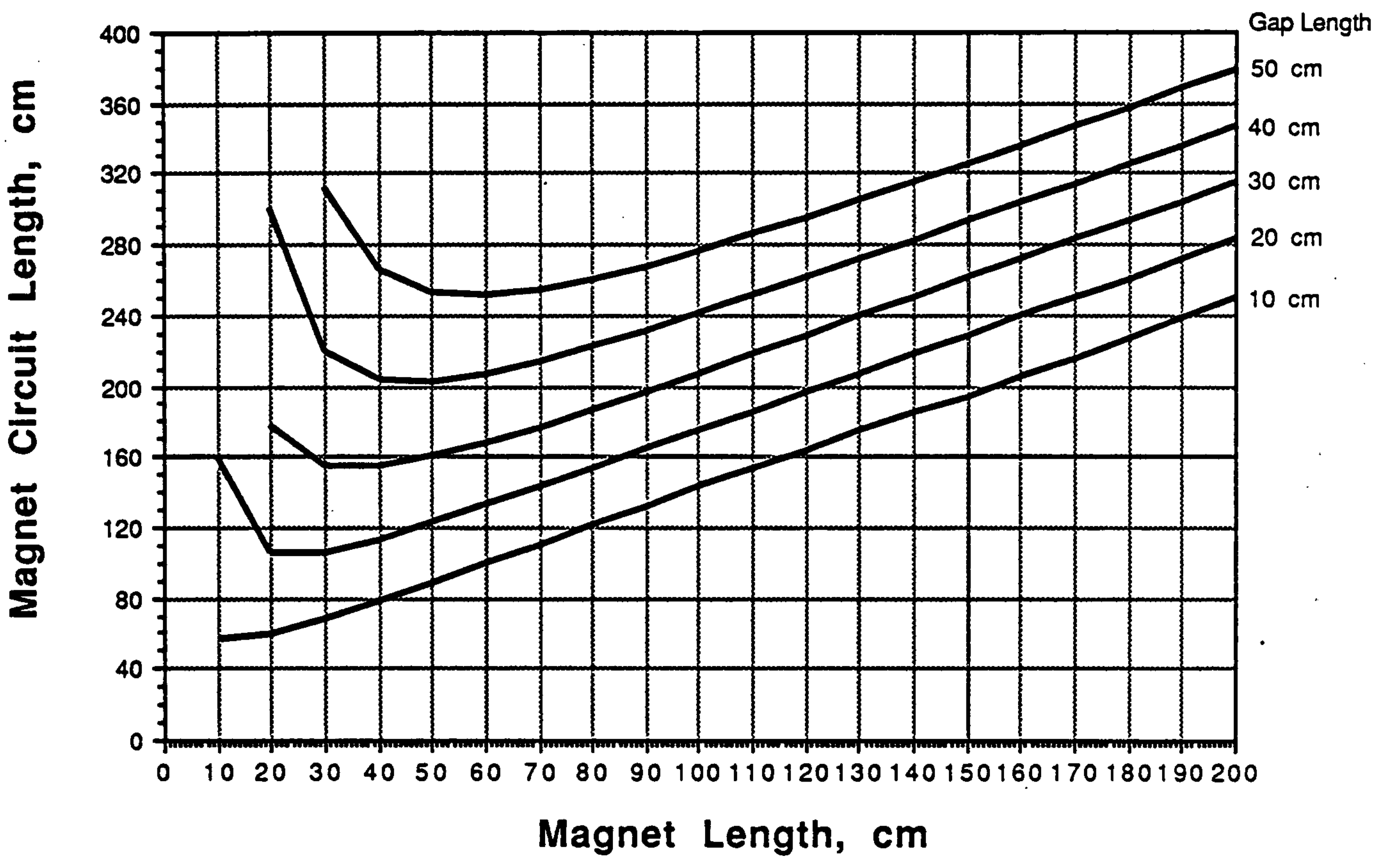


Figure 17 - Plot Of Circuit Length vs Magnet Length For NdFe24

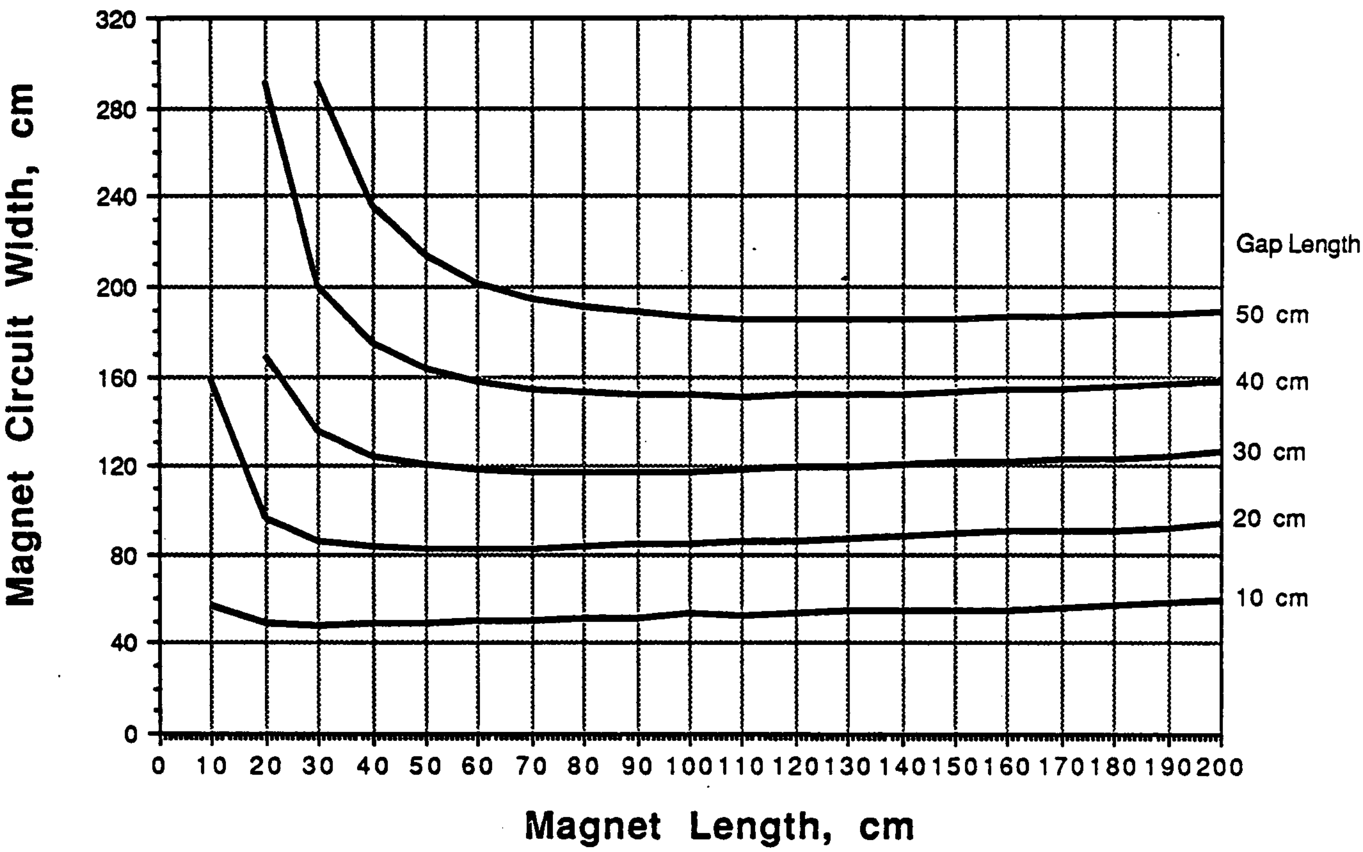


Figure 18 - Plot Of Circuit Width vs Magnet Length For NdFe24

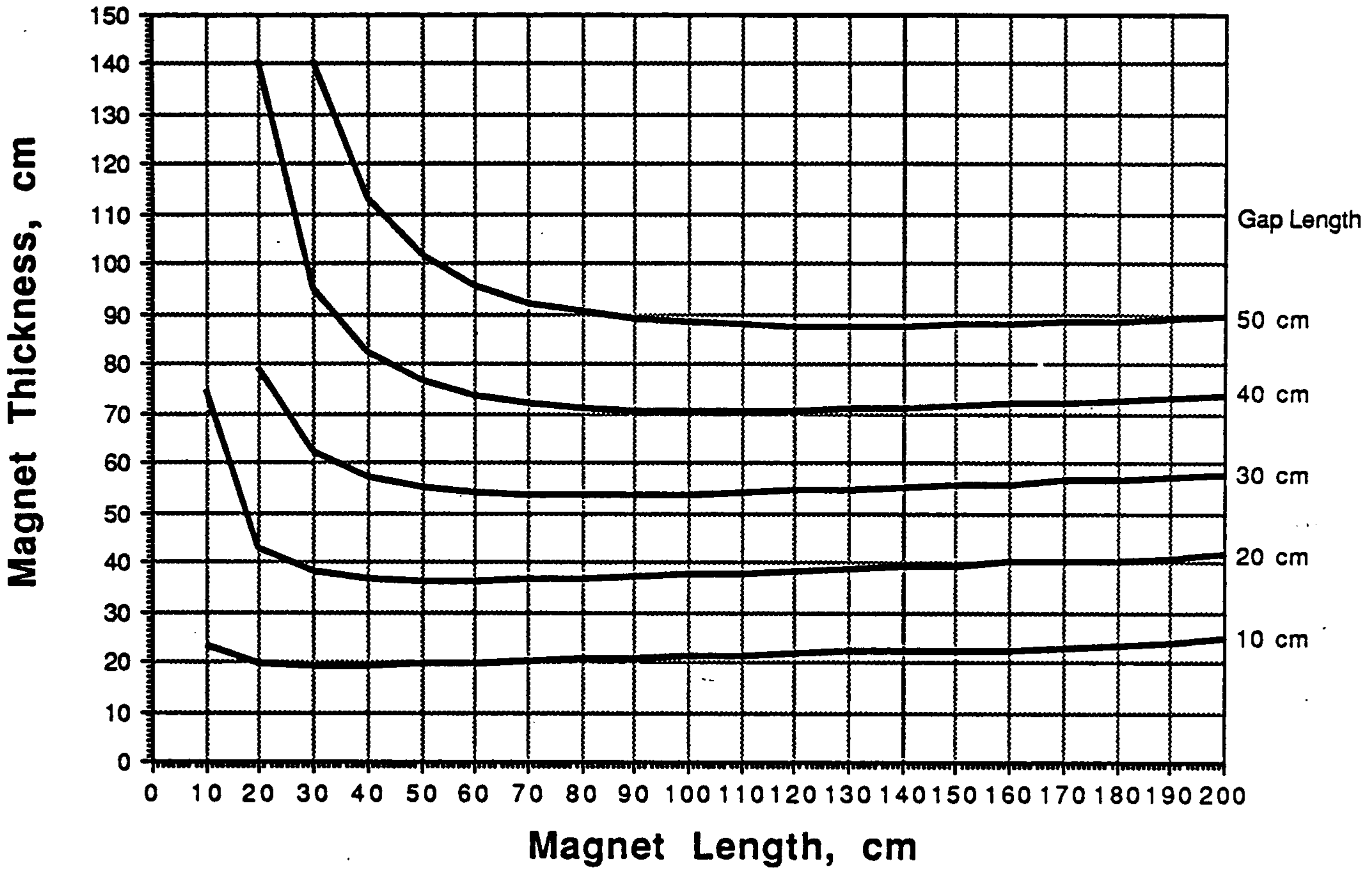


Figure 19 - Plot Of Magnet Thickness vs Magnet Length For NdFe24

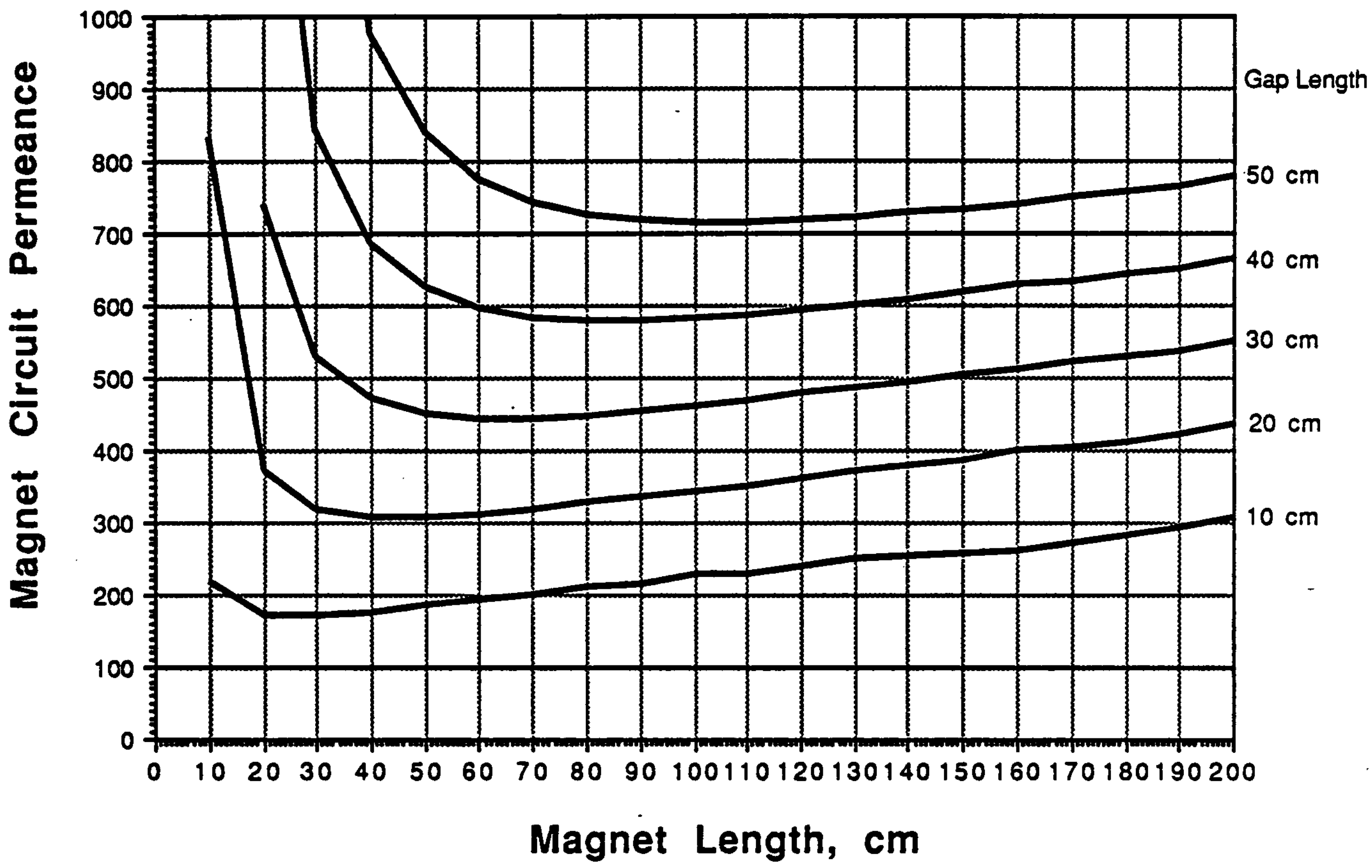


Figure 20 - Plot Of Circuit Permeance vs Magnet Length For NdFe24

NORMAL ELECTROMAGNET SYSTEM CONCEPT

The recommended concept for the magnetic suppression system is based on an electromagnet. This section describes the concept and presents the requirements of such a system.

Conceptual Design

Concepts involving the use of a normal electromagnet have been examined in this study. The most viable concept is shown schematically in Figure 21. The concept consists of a solenoid type electromagnet with a clear bore to accommodate the furnace module. The electromagnets are commonly constructed of a copper wire coil wound around a cylindrical form made of a non-magnetic metal. The winding are insulated with an epoxy or lacquer. The height of the magnet coil in this concept is sufficient to cover the melting zones of the furnace module under consideration. The magnetic field is set up by passing a current through the copper conductor. This magnet can operate at room temperature so a refrigeration system is not needed. Heat is generated by the coil, however, which will require an active cooling system to prevent overheating of the conductor. The electromagnet has a water jacket through which cooling water is passed to maintain the magnet within its proper temperature range. The magnetic field can be varied by adjusting the current flow through the copper coil. In addition to the magnet coil and the cooling subsystem, a power supply is also required which would be provided by the SSFF Core. The electromagnet can be turned off to permit sample changeout and on-orbit installation. Additionally, this permits magnetic shielding to be assembled on-orbit and the magnetic suppression system is not limited to the 700 kilograms per rack.

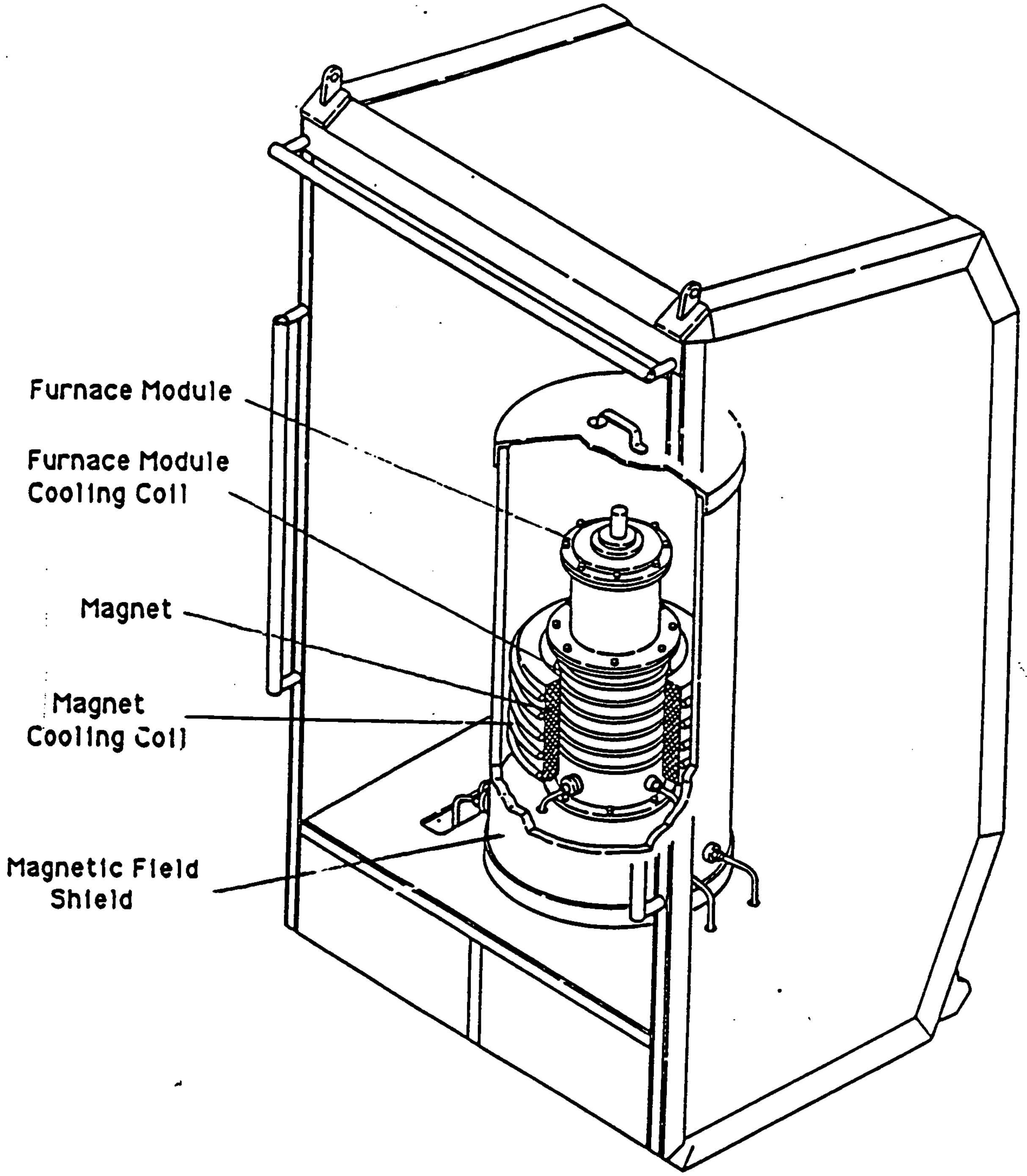


Figure 21 - Electromagnet Concept

Resource Requirements

The resource requirements for the concept utilizing a solenoid type electromagnet were based on accommodating a furnace module with an outside diameter of 20 centimeters and a hot zone length of 20 centimeters. It was assumed that the overall height of the furnace module was 60 centimeters. The form used for the coil winding was constructed of aluminum and was assumed to be 0.254 centimeter thick. The magnet wire used in the coil winding was constructed of copper. The requirements were estimated for a system with an emitted magnetic flux of 1.0 gauss as well as for 0.3 gauss.

Mass and Volume Requirements

For a given magnet coil diameter and coil height, it was found that for a desired magnetic flux at the center of the solenoid the mass of the coil will vary inversely with the power delivered to the coil. This is illustrated in Figure 22, which provides a plot of magnet coil mass versus power input to the coil for a 2000 gauss magnetic flux at various coil inside diameters. As can be seen from Figure 22, there is a trade off between the mass of the coil and the power requirement. For a 20 centimeter diameter furnace module, and a power requirement of 1000 watts, the mass of the coil is approximately 135 kilograms. Figure 23 is a plot of the outer diameter of the magnetic coil versus the the power input for various coil inside diameters. For a 1000 watt power input and an inside diameter of 20 centimeters, the outside diameter of the coil is approximately 44 centimeters. The outer diameter of the coil is governed by the number of turns in the coil, the coil height and the diameter of the wire used in the coil. Thus the overall outside diameter of the coil is 44 cm which means that the inside diameter of the magnetic shield must be at least 44 cm. Using Figure 4 which is a plot of the emitted magnetic flux versus the required thickness of the magnetic shield, for a shield with an inside diameter of 44 cm and constructed of Alloy 1 , the required thickness for an emitted flux of 0.3 gauss is approximately 14.1 centimeters. For an emitted flux of 1.0 gauss the required shield thickness is approximately 13.6 centimeters. There is not much difference between the two values since for both thicknesses the flux in the shield material will be above the saturation value of 7500 gausses. This can be

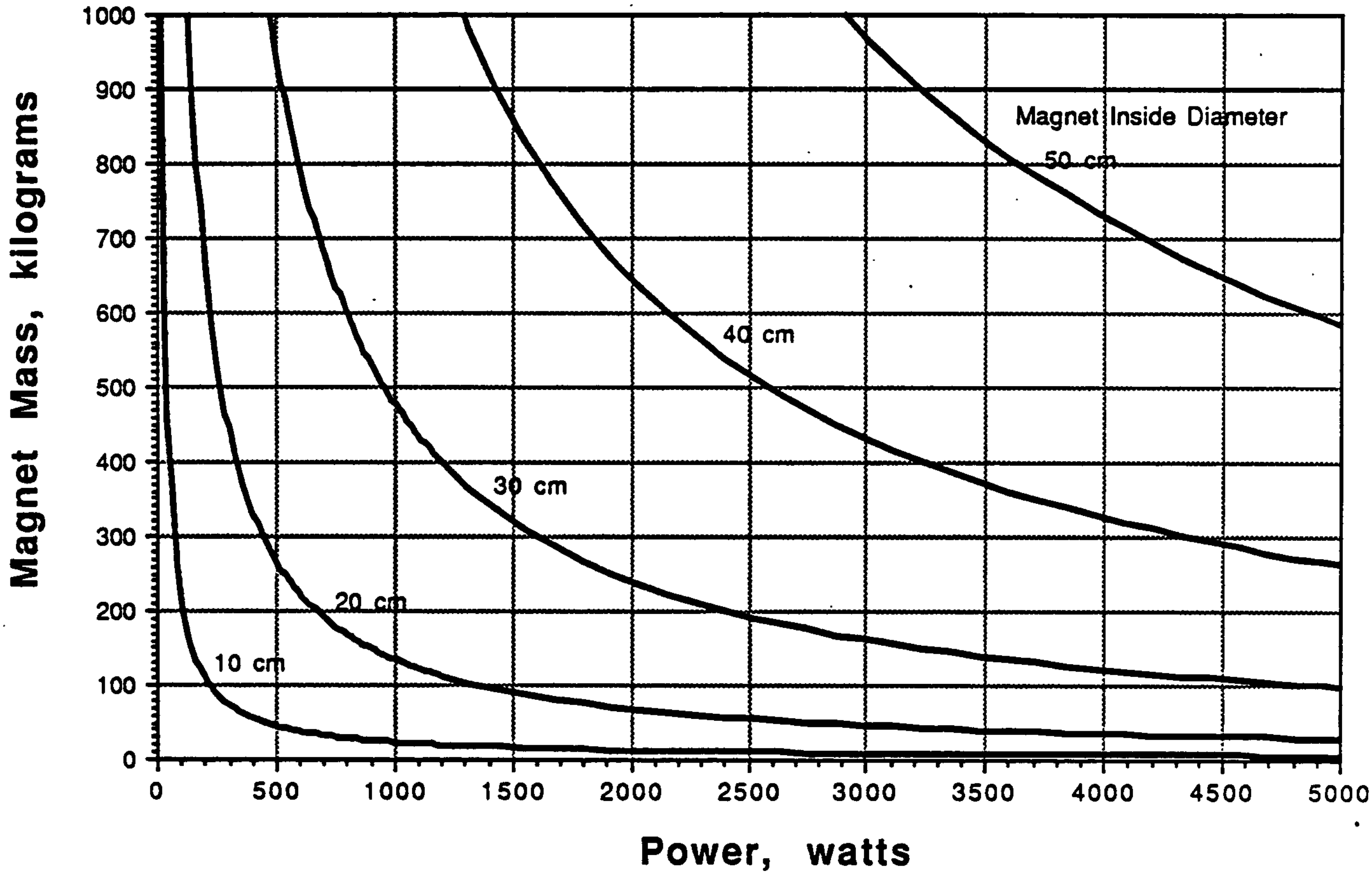


Figure 22 - Plot Of Magnet Mass vs Power

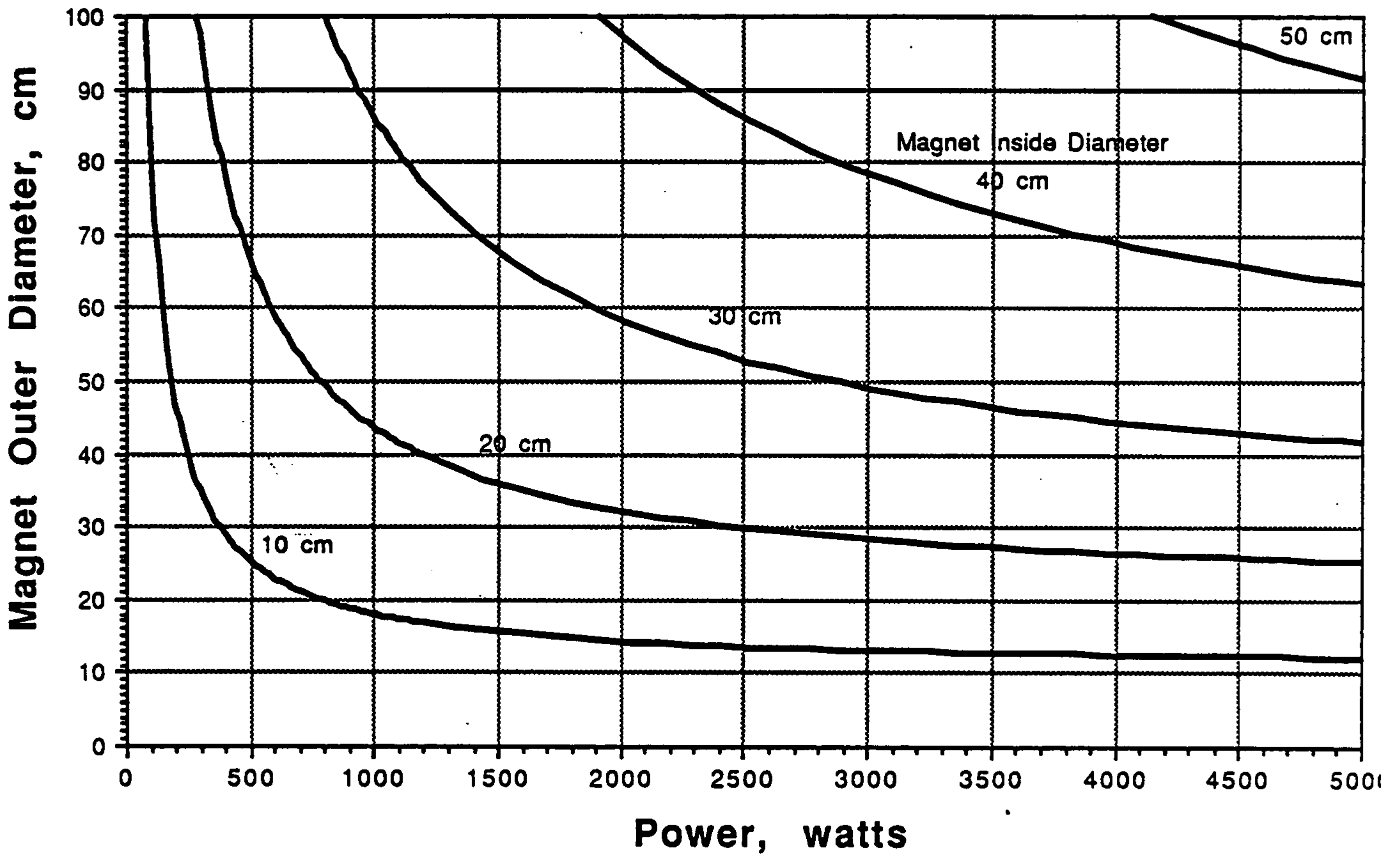


Figure 23 - Plot Of Magnet Outer Diameter vs Power

verified using Figure 7 which shows that for a shield with an inside diameter of 44 centimeters the minimum shield thickness to avoid saturation of the material is approximately 15 centimeters. Using Figure 6, for a shield with an inside diameter of 44 centimeters, and a thickness of 14.1 centimeters, the shield mass is approximately 1350 kilograms. For a thickness of 13.6 centimeters, the shield mass is approximately 1300 kilograms. Thus, the overall outside diameter of the magnetic shield is approximately 72.2 centimeters for an emitted magnetic flux of 0.3 gauss and 71.2 centimeters for an emitted flux of 1.0 gauss. Using Figures 22 and 23, the power and mass requirements for an electromagnet to accommodate other furnace module diameters can be determined as illustrated for the 20 centimeter diameter furnace module.

Power Requirements

In this study it was assumed that 120 volts dc power will be supplied to the electromagnet. Figure 22 shows that there is a tradeoff between the power requirement for the electromagnet and the mass of the electromagnet. A power requirement of 1000 watts was selected because it was felt this power level was viable in view of the fact that the furnace module will also require a certain amount of power which will depend on its design. Using Figure 22 however, the mass requirement for this concept can be determined for other power levels if desired.

Thermal Requirements

As mentioned above, the electromagnet will require active cooling. This is due to the joule heating of the magnet wire. The rate of heat removal must be at the same rate that it is produced to prevent the temperature from increasing. Assuming a temperature difference of 25 °F between the inlet and exit temperatures of the cooling water flowing in the water jacket surrounding the electromagnet, to provide 1000 watts of cooling, approximately 62 kilograms per hour of cooling water is required.

Data Requirements

There are no stringent data requirements envisioned for this concept except in the area of ensuring that the magnetic flux emitted from the system does not

exceed the specified limit of 0.3 gauss. If there are fluctuations in the current delivered to the electromagnet, the magnetic flux produced will also fluctuate and emissions could exceed the limiting value. For this reason the current, must be monitored and provisions put in place to control the effects of current surges which may impact the data requirements of this concept.

Venting Requirements

No venting requirement has been identified for this concept

Consumables

No consumables requirement has been identified for this concept.

CONCLUSIONS

Based on the resource requirements estimated, it appears that concepts involving electromagnets show the most promise.

The superconducting magnet systems appear to be much to complex and massive with technical risk associated with the handling and safing of the cryogenic fluids. Space Station Freedom resources probably will not support the venting, consumables and/or power. The payload volume of a rack is too confining for the differences in temperature between a high temperature furnace and a cryogenic magnet..

The mass and volume penalties of using a permanent magnet are very high. Considering that the maximum rack load at launch is 700 kilograms and the stringent requirement for shielding, there will very little volume for a furnace. The permanent magnet must be shielded at all times and the entire apparatus must be launched assembled. Estimates show that a furnace overall length could not exceed 25 centimeters. The design of permanent magnet systems is very specialized technologically.

With the electromagnet based systems, the field strength can be controlled, the design technology is less specialized than that of permanent magnets, and the cost will probably be lower than that of permanent magnets. The electromagnets have potential limitations in that electrical failures of surges could produce hazards, repairs and burnout occur due to aging, and they are more sensitive to shocks and vibrations than permanent magnets. The use of an electromagnet is recommended for this system. The electromagnet can be launched without shielding since there is no magnetic flux when there is no current flow. In this case, there would be on-orbit assembly which demand crew time. If the electromagnet based system is launched fully assembled, estimates show that the maximum furnace outside diameter which could be accomodated would be 14.5 centimeters.

Table 2 shows a comparison of the driving resources for the permanent magnet and electromagnet concepts.

It is recommended that lower field strength magnets be considered for this type of system. Due to the physical dependancies of the furnace on the magnet, it is recommended that this system be incorporated into a unique furnace module. This recommendation was accepted at the science Requirements Workshop on May 21, 1990.

Table 2 - Summary Of Driving Resource Requirements For Permanent Magnet and Electromagnet Concepts

Furnace Size - 20 cm OD X 50 cm length
Magnetic Field - 2000 Gauss

	Permanent Magnet	Electromagnet	
		0.3 G Leakage	1.0 G Leakage
Magnet Mass, kg	>4000	150	150
Shield Mass, kg	>10000	1350	1300
Total Mass, kg	>14000	1500	1450
Total Volume, (w X h), cm	300 x 300	72.3 x 88.3	71.2 x 87.2
Power, Watts	0	1000	1000
Thermal, Watts	0	1000	1000

320RPT0010

REPROGRAMMING OF EXPERIMENT COMPUTERS TRADE STUDY FOR SPACE STATION FURNACE FACILITY

DR-2

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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320RPT0010

REPROGRAMMING OF EXPERIMENT COMPUTERS TRADE STUDY FOR THE SPACE STATION FURNACE FACILITY

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

Prepared by:

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ABSTRACT

This trade study identifies the types of software that will need to be reprogrammed for SSFF and its associated furnace modules, discusses several techniques for accomplishing the reprogramming and compares several non-volatile storage technologies for utilization in the Space Station Furnace Facility (SSFF) including: optically recordable disks such as a Write Once Read Many (WORM) drive and Compact Disk Read Only Memory (CDROM), Removable Hard Drive, EEPROM Cartridges, and magnetic tape. Each of the considered technologies have their own benefits and constraints and this report seeks to find the optimum choice for use in the Space Station Furnace Facility. Of the different technologies evaluated, it was decided that the EEPROM Cartridge was the best choice. The EEPROM is a solid state technology which is a completely stable storage media and, in addition to having low weight, size and power specifications, it has no mechanical parts that could cause failure. The second choice was the Removable Hard Drive (RHD). The RHD scored closely to the EEPROM Cartridge in most areas; however, it is not as rugged as the EEPROM and it does have mechanical parts that could cause concern. A summary of the other technologies and their ranking scores is shown in Tables 1 through 6 in Appendix A. With the fast improvements being made in the capabilities of non-volatile storage media and the associated hardware, the technologies identified in this report should be examined on a continuous basis.

This document was submitted by Teledyne Brown Engineering in support of Contract No. NAS 8-38077.

ABBREVIATIONS AND ACRONYMS

BER	Bit Error Rate
CCU	Core Control Unit
CDROM	Compact Disk Read Only Memory
CMCU	Core Monitor and Control Unit
DCMU	Distributed Core Monitor Unit
DMS	Data Management Subsystem
EDAC	Error Detection and Correction
EEPROM	Electrically Erasable Programmable Read Only Memory
FAU	Furnace Actuator Unit
FCU	Furnace Control Unit
I/O	Input/Output
MSU	Mass Storage Unit
MTBF	Mean Time Between Failures
NASA	National Aeronautics and Space Administration
RAM	Random Access Memory
RHD	Removable Hard Drive
ROM	Read-Only Memory
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
STS	Space Transportation System
TDRSS	Tracking and Data Relay Satellite System
WORM	Write Once, Read Many
ZOE	Zone of Exclusion (Loss of Signal)

EXECUTIVE SUMMARY

In order to facilitate a flexible approach to meeting requirements for multiple types of furnaces and to minimize the impacts on crew and uplink time, reprogramming capabilities for the experiment computers become necessary. This trade study was conducted to explore the various ways in which experiment computer systems on-board Space Station Furnace Facility may be reprogrammed. This report describes several methods for accomplishing the reprogramming and documents a conducted survey of some of the different types of physically transportable, rugged, programming technologies available such as: Compact Disk Read Only Memory (CDROM) drives, optically rewriteable drives, Write Once Read Many (WORM) drives, EEPROM cartridges, Removable Hard Drives (RHD), and magnetic tape drives. Characteristics that were surveyed were compiled from the information contained in manufacturers' data sheets and reports currently available from other studies.

This task involves several levels of reprogramming capability. At the present time, there have been six levels identified, based on frequency of need to program. These levels are listed in increasing frequency of reprogramming need and are as follows: 1) Bootstrap software, 2) Operating software, 3) Core Application software, 4) Core Configuration software, 5) Experiment Application software and 6) Sample profiles. Change authorization is required for each level by one or more of the levels above it. Requiring change authorization assures that the correct software is reprogrammed at the proper time and in the proper order.

Reprogramming the different levels of software will be accomplished by three methods: 1) reprogramming on the ground, 2) reprogramming through uplinking capabilities and 3) reprogramming by transferring "canned" programs from a non-volatile storage media (that can be launched with the racks) to the SSFF Core Control Unit (CCU). The second and third methods will be used for reprogramming SSFF software already installed into the SSFF racks on-orbit. The first method will be used whenever a new integrated experiment rack is built, before it is launched and installed into SSFF on-orbit.

The majority of this trade study deals with a survey of available technologies for the non-volatile storage media. A criteria list was compiled based on: 1) an analysis of the data management requirements of SSFF and its associated furnace modules and 2) the requirements associated with reprogramming the software for SSFF and its associated furnace modules. Once the evaluation criteria were determined, target (desired) values for the criteria were generated based on given and derived requirements for functional capability, resources, maintainability, qualification status and cost. Then, the criteria were weighted based on these target values. A criteria matrix was built for each technology, and the data collected from specification sheets and other studies was used to fill in the matrix. Each candidate was scored based on how closely it met

the target values and a total score was generated. The technology with the highest score was recommended as the one most likely to satisfy the requirements of the reprogramming task.

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1. OBJECTIVE

The objective of this trade study is to determine the optimum implementation concept and software storage technologies for the reprogramming of the experiment computers associated with the Space Station Furnace Facility (SSFF). It consists of a description of the SSFF DMS hardware, identification of SSFF software types and associated components, a discussion of reprogramming methods, an evaluation of implementation concepts and a survey of the currently available software storage technologies that are flight-qualified, or that can be easily qualified. Included in this report are tables containing the calculated scores of each of the technologies surveyed, as well as recommendations for the implementation concept and technologies that should be utilized to provide the reprogramming capabilities necessary to meet SSFF requirements.

2. SYSTEM DESCRIPTION

The Space Station Furnace Facility (SSFF) will be a payload for use on Space Station Freedom (SSF) for the processing of metals in a microgravity environment. The microgravity environment will be used to reduce the effects of convective flows around the hot/cold interface during processing of the material. This processing will produce homogeneous crystallization of materials and samples that can reveal knowledge of the materials that cannot be produced in a one gravity environment.

The SSFF will be a three-rack facility for Space Station Freedom which will be utilized for conducting experiments in the US-Lab Module A. The first rack (or Core Rack) will contain the general utilities required by the furnaces for processing materials and includes the SSFF Data Management Subsystem (DMS) computer services (such as SSF interface, data monitoring, processing, storage, and transmission). The other two racks, Experiment Racks 1 and 2 (ER1 and ER2), will contain the furnaces to be operated by the facility, and will be configured so that either one or both furnaces can be operated. These racks will also contain the specialized monitoring/control units and the majority of the Mission Peculiar Equipment (MPE) needed by the furnaces.

In addition to the hardware provided by SSFF to support the operation of the furnace modules within each experiment rack, SSFF software will be provided that will support flexible configurations of the experiments. Central to this flexibility is the ability to reprogram the experiment computers.

Many factors have contributed to the need for reprogramming capabilities for SSFF. With the advent of the restructuring activities, Space Station Freedom resources were diminished along with the allocations of these resources for the payloads. Impacts on crew time must be minimized and the contraints associated with uplinking activities will be of major concern. The SSFF will need a capacity for large amounts of experimental profiles and profile variations to support its requirements for flexibility, autonomy and reliability; however, the capacity for storage on the Payload Mass Storage Unit (MSU) has been steadily reduced as SSF development continues. All these factors have helped to identify the need for integrating reprogramming capabilities into SSFF.

2.1 IDENTIFICATION OF SOFTWARE TYPES

SSFF will have six different types of software, each on a different level of reprogramming frequency. These types are identified below in ascending order of reprogramming frequency (i.e., Type #1 is the least often reprogrammed; Type #6 is the most often reprogrammed), as follows:

Type #1 Bootstrap Software - Not reprogrammable except by special dedicated electrical interface to each unit (not writeable by local processor/controller). Frequency of reprogramming - almost never, only if there is a significant change or enhancement in the computer architecture, i.e. faster I/O ports, new ROM technology, etc. Change authorization is accomplished by hard-wired enable (i.e. connector pin(s)), requires crew.

Type #2 Operating Software - Communications SW, utility SW, etc. Frequency of reprogramming - slightly more frequent than Type #1, becomes necessary with system upgrades or changes to communication/utility protocols. Change authorization enabled by Type #1 SW, no crew required.

Type #3 Core Application Software - Uses Type #2 to operate the SSFF. Frequency of reprogramming - whenever core hardware is reconfigured or when a new furnace module is installed. Change authorization enabled by Type #2 SW, no crew required.

Type #4 Core Configuration Software - Core data (probably data tables) that is revised for each new configuration of furnace modules that requires additional hardware such as sensors and effectors. Frequency of reprogramming - whenever core hardware is reconfigured or when a new furnace module is installed. Change authorization enabled by Type #2 SW, no crew required.

Type #5 Experiment Application Software - Software and data associated with the operation of the furnaces. Frequency of reprogramming - whenever a new furnace module is installed. Change authorization enabled by Type #3 and #4 SW, no crew required.

Type #6 Sample profiles - Operational parameters for each processing run of the sample. Frequency of reprogramming - every time new sample is run. Change authorization enabled by Type #5 SW.

These six types of software will be distributed among the SSFF DMS processors. Figure 2-1 illustrates the DMS hardware concept configuration which contains the processors in which the software will reside. Software types 1 through 4 are SSFF provided software and will be distributed among the core rack and experiment rack processors, i. e. the Core Control Unit (CCU), the Core Monitor and Control Unit (CMCU), the Furnace Control Unit (FCU), the Distributed Core Monitor Unit (DCMU) and possibly the Furnace Actuator Unit (FAU). These four types have been partitioned into a modular set of SSFF software components as illustrated in Figure 2-2. Types 5 and 6 will be built by the furnace developers and will reside in the SSFF provided processors in the experiment racks, i. e. the FCU and possibly the FAU.

2.2 REPROGRAMMING METHODS

The reprogramming task will encompass three methods: 1) reprogramming on the ground, 2) reprogramming through uplinking capabilities and 3) reprogramming by transferring pre-defined programs from a non-volatile storage media (that can withstand being launched with the racks)

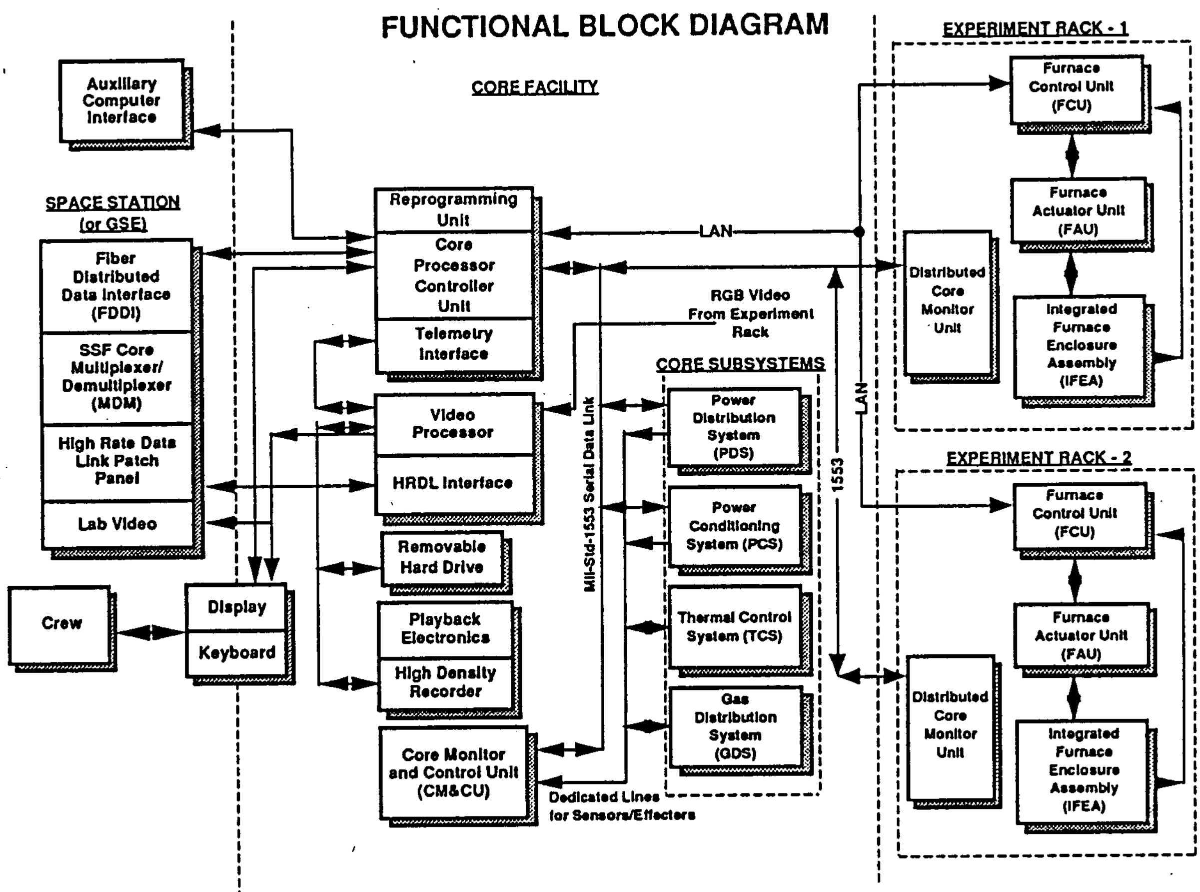

FIGURE 2-1. SSFF DMS FUNCTIONAL BLOCK DIAGRAM

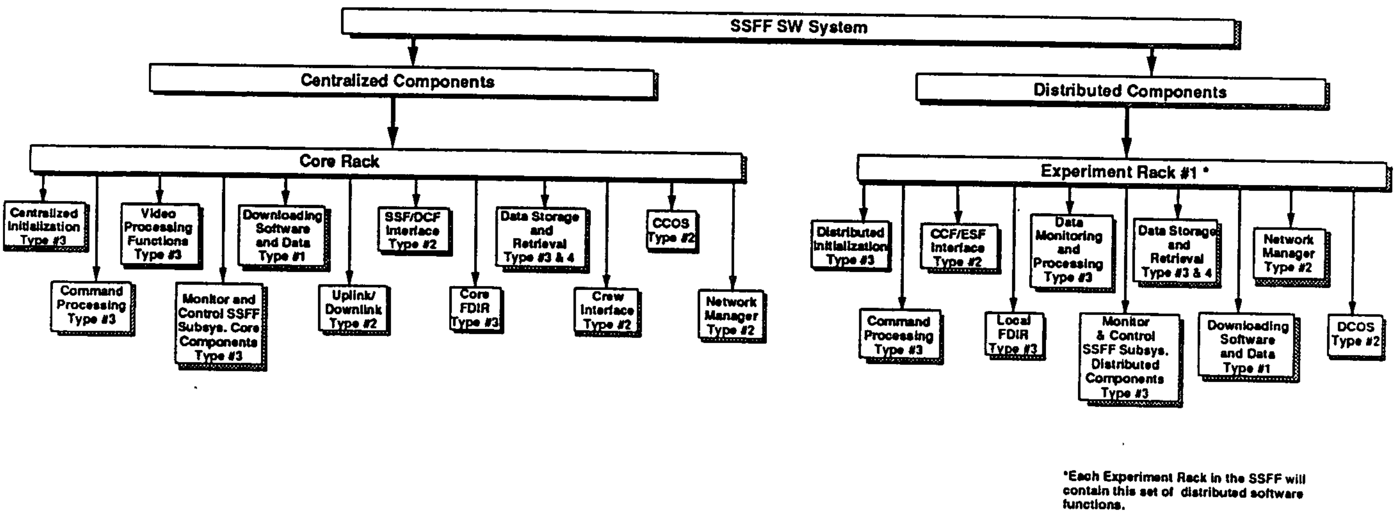

FIGURE 2-2. SSFF SOFTWARE COMPONENTS

to the SSFF CCU.

Once SSFF racks have been launched, installed into the SSF and activated for processing samples, contingencies will most likely occur. These contingencies can be handled from the ground by the users through the second method, reprogramming through the uplinking capabilities. Such contingencies should be a non-frequent occurrence since thorough testing of the software and hardware will be performed on the ground before installation into the SSF. This will keep uplinking requirements minimal. Figure 2-3 illustrates the basic uplinking path for payloads on SSF.

The first method, reprogramming on the ground, will be required whenever a new experiment rack is built and loaded with new furnace module(s). Software compatible with new hardware and new experiments can be installed into the FCU and the integrated configuration can be tested on the ground before being launched as a unit.

The third method of reprogramming and the focus of this trade study is on-board reprogramming. Figure 2-4 is a high level diagram of the on-board reprogramming flow. This type of reprogramming will be required: 1) whenever new furnace modules are installed into the SSFF racks already resident on the SSF, 2) whenever the users want to run new experiments in the same furnace module and 3) whenever new samples are run using the same experiment parameters and the same furnace modules. The reconfiguration software and data will be contained in a catalog of programs residing in non-volatile storage media on board. The user will be able to select new configurations, experiments or operational parameters simply by uplinking a selection from this catalog. This scenario will require much less time and effort than sending up entire programs through the uplinking path.

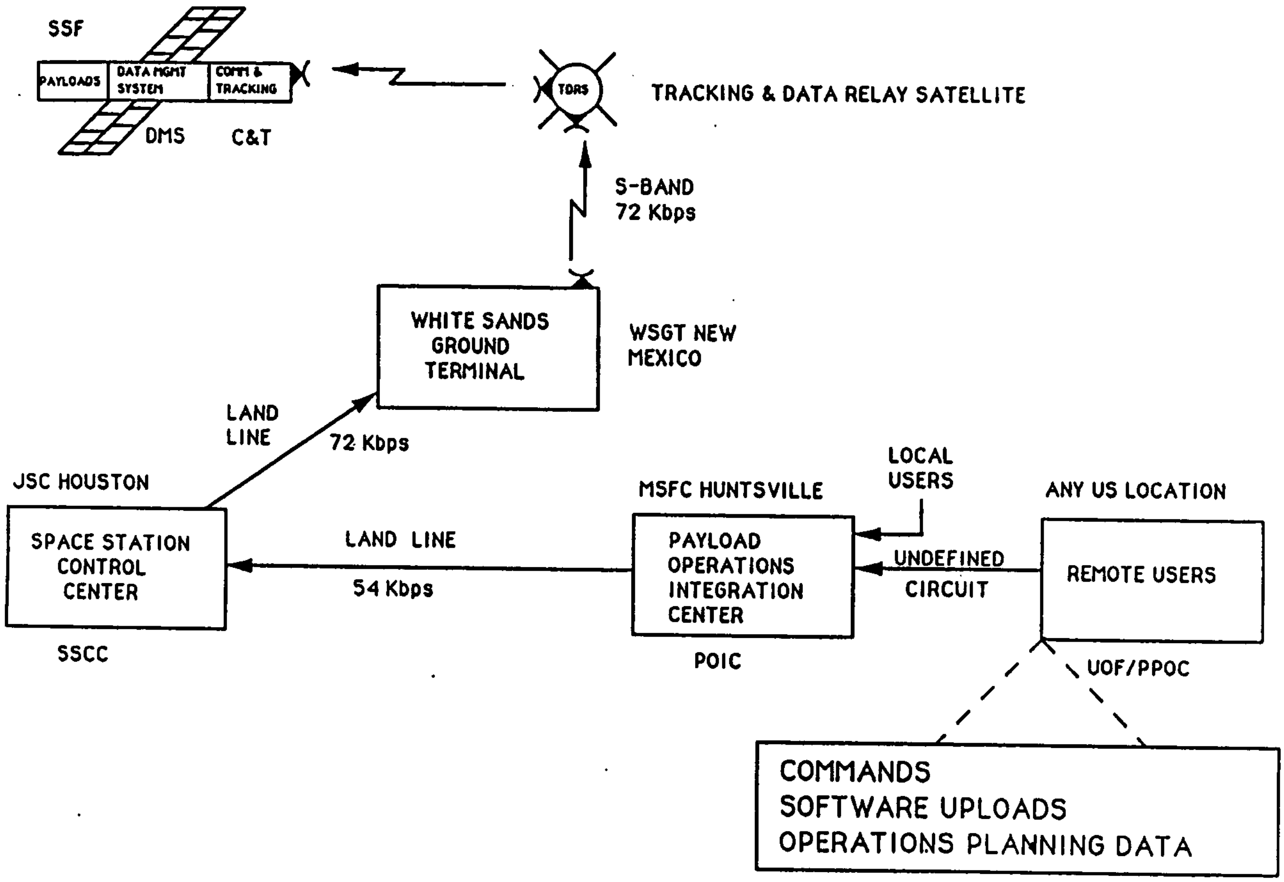

FIGURE 2-3. REPROGRAMMING SSFF THROUGH UPLINK

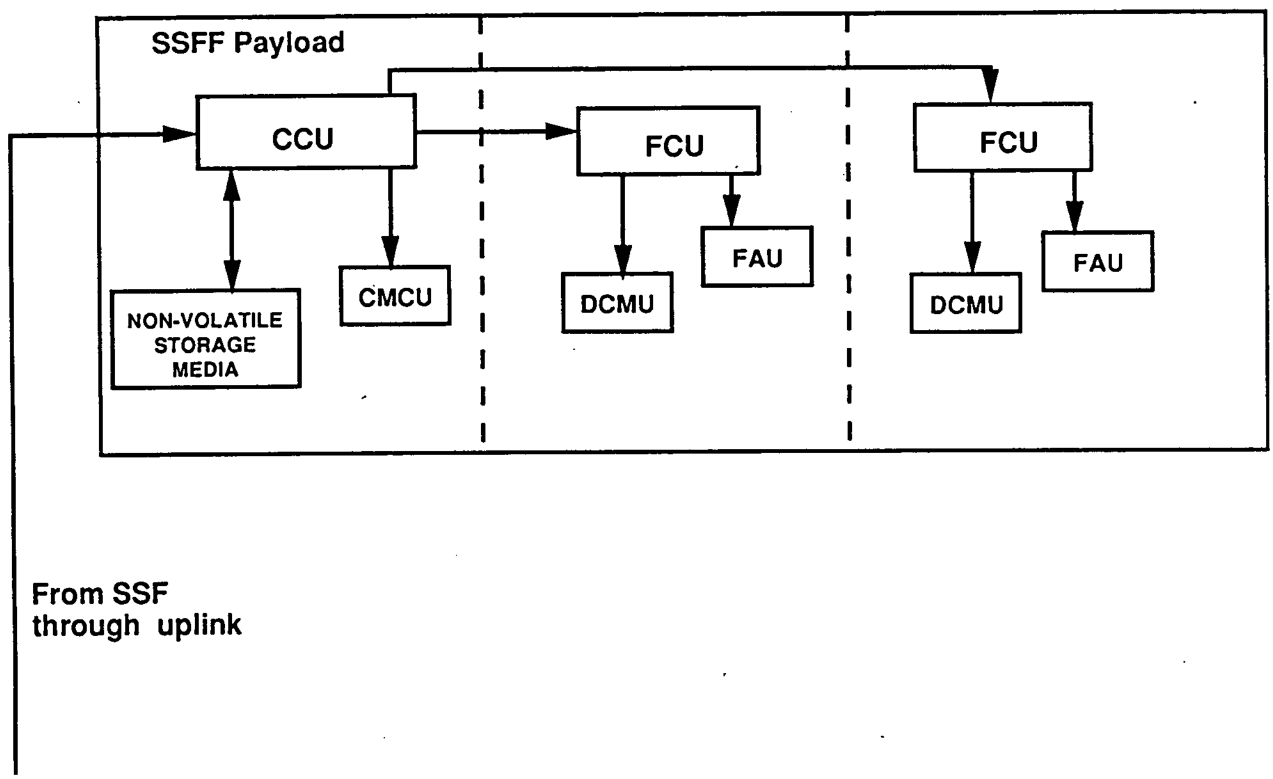

FIGURE 2-4. REPROGRAMMING SSFF ON-ORBIT

3. STUDY METHODOLOGY

The first step of this trade study was to perform an analysis of the DMS requirements for the SSFF and its associated furnace modules together with establishing the scope and methods required to accomplish the reprogramming task and support the science requirements. Next, candidate technologies most likely to meet the specifications for use aboard SSFF were identified. A criteria list for the candidate technologies was compiled based on the given and derived requirements mentioned above. The list includes five major categories of criteria: functional capability, resource requirements, maintainability, qualification status and cost. These categories were broken down further into individual criteria. Once the evaluation criteria were laid out, target values were assigned based on the requirements analysis. The major categories were assigned a percentage weight based on relevant importance. As a starting point, the total percentage was divided by the number of individual criteria in the category and that value became the maximum weight for the individual criteria. After that step was completed, the more important criteria such as weight and size were weighted heavier and less important criteria such as operating temperature were weighted lighter. Each candidate was scored on how closely it met the target values and a total score was generated. The technology with the highest score was recommended as the one most likely to satisfy the requirements of the reprogramming task for SSFF.

Vendors were contacted and surveyed and data sheets from the vendors and other studies were collected in order to obtain information for determining the criteria and evaluating each technology. A criteria evaluation table was built for accummulating the collected data and generating scores. The quantitative results of the surveyed data, weight ranges, actual weights and total scores for each technology considered are presented in Tables I-VI in Appendix A.

4. REQUIREMENTS DEFINITION

The SSFF SOW paragraph 5.5.9, WBS 2.1.2, calls for an optimum means of reprogramming experiment computers to process sets of samples. It states, "Find the best method for most reliable, fault tolerant transferral of data requiring a minimum of crew interaction and training. Encompass microgravity operations, EMI and radiation problems relevant to space operation. Use flexible methods allowing easy updating and modification to accommodate experiment condition.

Generate a draft report of the findings.

Deliverable products:

1) Report detailing the results of the reprogramming study with a comparison of approaches and a recommended approach."

5. GROUND RULES AND ASSUMPTIONS

1. The technology chosen must be functional and safety compliant in an SSFF environment.
2. The technology chosen must have a large capacity in order to support growth, as well as accommodate a large variety of experimental profiles, in a small volume.
3. The technology chosen must be reliable (high Mean Time Between Failures (MTBF)), with a minimum of mechanical parts, and/or contact with the storage media, in order to keep wear to a minimum.
4. The technology must be modular to facilitate upgrading in the design, growth, and Orbital Replacement Unit (ORU) change-out.
5. Installation/deinstallation must take a minimum of crew time and training.
6. Storage capabilities of technologies did not consider data compression.

6. CONCEPTS/OPTIONS DESCRIPTIONS

The implementation concepts and technologies considered for accomplishing the reprogramming task are described in this section.

6.1 IMPLEMENTATION CONCEPTS CONSIDERED

The following concepts were considered for implementing the reprogramming of the SSFF computers.

6.1.1 Instruction Set

Each sample processed would have an EEPROM instruction set that could be read by the SSFF computer.

6.1.2 Uplinking Programs

The SSFF computers would be reprogrammed by uplinked commands and data from the ground.

6.1.3 Payload Mass Storage Unit

SSFF software and data required to reprogram the SSFF computers would be stored on the Payload MSU and retrieved when necessary. This unit is part of Space Station Freedom Data Management System and limited space will be available for use by all SSF payloads.

6.1.4 Centralized Local Storage Unit

SSFF programs and data required to reprogram the SSFF computers would be stored on one of the following non-volatile forms of media: a disk drive with removable media, a removable disk drive, a solid state memory cartridge or a tape drive. The programs and data would then be downloaded to the SSFF Data Management System when necessary.

6.2 TECHNOLOGIES UNDER REVIEW

The following non-volatile media technologies were considered for storing the SSFF software and data required to reprogram the SSFF computers.

6.2.1 Disk Drives

There are several types of drive technologies available; however, some technologies lend themselves better to a micro-gravity environment than others. Floppy drives, for instance, were found to be difficult to implement in microgravity. Their light weight and non-rigid construction requires earth gravity in order to keep the media in contact with the read/write head. Therefore, floppy drives were not considered for this study. The magnetic and optical drives that were

considered are discussed below.

6.2.1.1 CDROM (Compact Disk Read Only Memory encased in a cartridge) - This media has Error Detection and Correction (EDAC) capabilities, active servo tracking, immunity to damage and radiation, minimum of moving parts, minimum of contact with media, large storage capacities and is a state-of-the-art technology. It is a fixed media meaning it cannot be written to once it has been loaded with data.

6.2.1.2 WORM(Write Once Read Mostly) Drive - This media has EDAC capabilities, active servo tracking, immunity to damage and radiation, minimum of moving parts, minimum of contact with media, large storage capacities and is state-of-the-art technology. WORM media is semi-fixed meaning it can be written to only once after it has been loaded with data.

6.2.1.3 Optical Disk Storage - The optical disk is the same type of technology as the CDROM and the WORM technology with slight differences in the media composition and the read/write/erase head. This media is categorized as semi-fixed; however, it can be written to more than once under certain conditions. As with the WORM drive, the optical drives have a minimum of moving parts.

6.2.1.4 Removable Hard Drive - Ruggedized, removable hard drives are available with the ability to write-protect portions of or the entire drive. They have EDAC capabilities, adequate storage capacity and full write capability. These drives are mechanical.

6.2.2 EEPROM (Electrically Erasable Programmable Read Only Memory) Cartridge

This technology is a solid state memory with no moving parts, EDAC capable, very rugged, but has a lower storage capacity than some of the magnetic and optical media. This technology has already flown on Space Lab.

6.2.3 Tape Drive

Tape Drives are readily available with high capacity, low Bit Error Rates (BER) and high reliability. Tape technology has been around for many years with both longitudinal and helical technologies available. This technology incorporates EDAC capabilities and has flown aboard a wide variety of spacecraft (including Spacelab and the Space Transportation System (STS) Shuttle).

7. EVALUATION CRITERIA AND WEIGHTING

7.1 DEFINITION

The candidate technologies for the reprogramming of experiment computers were evaluated on the following criteria which were grouped into five categories.

7.1.1 Functional Capability

7.1.1.1 Storage capacity of the media - The value of this criteria was based on how much data could be stored in a single unit, i.e. one CDROM, one WORM, one EEPROM cartridge, etc. compared to what was required for the reprogramming software.

7.1.1.2 Data transfer rate - The value of this criteria was based on a comparison of the number of megabytes per second that could be output by the device and the target value.

7.1.1.3 Access method - The maximum weight for this criteria was allowed if the data on the device could be accessed randomly, which would be the fastest and most efficient method; zero was given if the data had to be accessed sequentially, such as in tape drives.

7.1.1.4 Support Circuitry Required - The maximum weight for this criteria was allowed if the device could connect to the SSFF DMS using a standard interface i.e., 1553B bus, SCSI bus, RS-422. If it required a specially designed interface, weights were based on the complexity of that interface.

7.1.1.5 Ease of programming media - This criteria was rated 1 or 0 where a 1 was given if the device could be programmed by the user in-house (like EEPROM cartridges) or a zero was given if it would be necessary to ship the device to a special production facility for programming (such as the CDROM which must be mass produced).

7.1.1.6 Write Capability (or Modifiability) - This criteria was weighted based on whether or not the information on the device could be written over, or modified, once it was programmed with software and data.

7.1.1.7 EDAC (Error Detection And Correction) capabilities - This criteria was weighted based on whether or not the device or media had this capability. It was considered to have this capability if either EDAC would be part of the procured package or could be a software enhancement developed by the user.

7.1.1.9 BER (Bit Error Rate) - This criteria was weighted based on a comparison of the number of media errors that could be expected from this type of device and the target value. This criteria applies primarily to tape drives where the possibility of burst errors exist (a burst error occurs when a section of the tape is damaged from dirt or demagnetism); however, data for this criteria was available for the other technologies, so it was included in the list.

7.1.2 Resource Requirements

7.1.2.1 Power consumption (Watts) - This criteria was rated based on a comparison of the power consumption for this device and the target value. For instance, if a technology could consume 35 watts of power and the target value was 10 watts, 35 is 3.5 times larger than 10, so the maximum weight for this criteria was multiplied by approximately 0.3. The resulting number was placed in the criteria evaluation table.

7.1.2.2 Weight (kg/lbs) - The weight for this criteria was determined by calculating a ratio of actual weight to target weight. This ratio was multiplied by the maximum weight value and the resulting number was placed in the criteria evaluation table.

7.1.2.3 Size (cubic centimeters) - The weight for this criteria was determined using the same method as the one for weight.

7.1.2.4 Operating temperature - The weight for this criteria was determined by calculating a ratio of the actual temperature range to the target temperature range. For instance, the CDROM could operate from 10 degrees to 40 degrees centigrade. This is a temperature range of 30 degrees. The target range is 150 degrees (-50 to 100 degrees centrigrade). The ratio is 1 to 5, so the maximum weight value was multiplied by 0.2 and the resulting number was placed in the table.

7.1.2.5 Crew Time for initial installation - The weight for this criteria was based on an estimation by the researchers of how long it would take for the crew to install the device and/or the media the first time after launch, either less than or longer than 5 minutes.

7.1.3 Maintainability

7.1.3.1 Durability / MTBF - The weight for this criteria was calculated using a ratio of the actual Mean Time Between Failures (MTBF) and the target MTBF. This ratio was multiplied by the maximum weight value and the result recorded in the table.

7.1.3.2 Vibration, Non-operating - This criteria was the level of vibration the device could withstand without sustaining damage. A ratio of actual and target values was used to calculate the actual weight.

7.1.3.3 Shock, Non-operating - This criteria was the level of shock the device could withstand without sustaining damage. Again, a ratio was used to calculate the actual weight.

7.1.3.4 Transportability - This criteria considered the size of the device, the ease of installation such as wiring up the drive versus slipping a cartridge into a slot and ruggedability. Transportability was rated with a scale of 1 to 10 with 1 being most difficult to transport and 10 being easiest. Determinations of where the technology fell within this scale was based on the researchers experience and knowledge together with data sheet information.

7.1.4 Qualification Status

7.1.4.1 Ease of qualification - This criteria weight was based on a scale of 1 to 10 with 1 being the most difficult to qualify and 10 being the easiest. Determination of where the technology fell within this scale was subjective based on the experience of the researchers.

7.1.4.2 Space or Military qualification - This criteria was weighted on whether the device was space or military qualified or neither. Space qualification was allowed the full weight value, military was allowed 50% and neither was given zero.

7.1.5 Cost - This criteria included the cost of the hardware, the media and the production. Cost of qualification was not included in the values for this criteria but was estimated to be approximately $50 K for every technology.

7.2 WEIGHTING

Methodologies for weighting trade study criteria are abundant and can vary with each set of researchers. Likewise, the weighting methodology employed in this study was subjective and based on the experience of the researching team. The methodology engineered for this report is described in the following paragraph.

First, each of the five categories of criteria were assigned a percentage number based on degree of importance; all the percentages together equaled 100%. For instance, the category Functional Capability was assigned 30%. As a starting point, the percentage numbers were divided by the number of individual criteria in each category to arrive at an initial maximum value for the weight range. After that was completed, specific criteria that were considered to be more important (in relation to the operating environment of the SSFF) such as weight and size were increased by an amount sufficient to reflect this importance. The minimum value for the range was always zero. If data for a certain criteria was not available or not applicable, then the number of individual criteria was decreased and this new number was divided into the total percentage resulting in new maximum weight values. In the case of Functional Capability for the CDROM, the weight range is 0 to 3.75 for each of the criteria (30 divided by 8 criteria for that category); however, the Removable Hard Drive does not have BER, so its weight range is 0 to 4.29 (30 divided by 7 criteria). To derive the actual weights for each of the criteria, the criteria was evaluated as described in Section 7.1. Once the actual weights were derived for every criteria, they were added up in order to generate the total score.

The criteria, its associated data, weights and scores for each technology are contained in Tables I - VI in Appendix A.

8. CONCEPTS/OPTIONS EVALUATION

8.1 IMPLEMENTATION CONCEPTS EVALUATED

8.1.1 Instruction Set

Physical implementation of this method would be difficult with each sample reading a corresponding EEPROM after being inserted into the furnace module assembly. This would be unreliable and there would be no centralized location for storage, retrieval and/or modification of these programs and data. The data flow would reflect poor engineering with data being transferred out of the furnace module to the FCU of the SSFF DMS. Electrical implementation would be difficult because of the necessity of having additional communication lines to and from the furnace module assembly . In addition, the SSFF, as a whole, would lose flexibility and modularity since it would not have the ability to upgrade or expand the systems and cabling that would be involved. Environmental susceptibility and corruption of the data would also be a major concern since verification and configuration control would be extremely difficult, if not impossible.

8.1.2 Uplinking Programs

Uplinking of programs to the Space Station Furnace Facility via TDRSS and the Space Station Freedom DMS system was reviewed as a possibility for reprogramming (See Figure 2-3.) This method would rely heavily on ground, TDRSS, and Space Station Freedom resources. Even though the SSFF would be capable of utilizing this method for uploading of programs, one of the problems associated with this method would be the SSF allocation for uplinking of payload data. The present maximum uplink allocation for all the payloads is 9 kilobits per second. This allocation would be available only when the SSF would not require it; usage would be on a first-come, first-serve basis; and uplinking would not be continuous because of Zone Of Exclusion (ZOE). SSF requirements for verification of command uplinks in the form of retransmission and security verification could quickly create bottlenecks for transmissions. The possibility of bottlenecks was one of the major drivers in identifying a need for reprogramming capabilities. Another major disadvantage would be the lack of non-volatile backup storage of the SSFF software. Backups could be essential if the CCU experienced a severe malfunction. Although transmission of complete programs, data sets, and scenarios could not be ruled out completely, this method would be most effective if reserved to handle contingencies and simple commands.

8.1.3 Payload Mass Storage Unit (MSU)

Using the Payload MSU was considered; however, like uplinking, it would suffer from the problems of a common resource; a number of payloads would be competing for the resources of the MSU, as well as the associated SSF services. Additionally, as SSF development has progressed, more of the payload MSU has been allocated for storage of the SSF DMS software

and misson operations data. There would be a possibility that by launch time of the SSFF, the MSU could be fully allocated by other users. On-orbit configuration control and qualification of stored data would be a problem because of the many users of the MSU and a corresponding slow access time. Access to the payload MSU must be done through the SSF DMS Services which could enhance any bottleneck problems. Because of all the problems that could be associated with the MSU, it was not considered a reliable candidate for reprogramming.

8.1.5 Centralized Local Storage Unit

This concept would be simple to implement and it would support the modular and flexible theme of the SSFF. The local storage unit would be independent of the Payload MSU and SSF DMS resources and would provide a centralized location for storage, retrieval and/or modification of the SSFF software and data. A major advantage would be the automatic provision of non-volatile backup storage. Another major advantage would be the capability of efficient on-orbit configuration control, verification and installation of new SSFF software and data. Future growth or incorporation of the latest technology would be easily implemented. Utilizing this concept, reprogramming could be as fast and reliable as RAM operations. This concept has been considered the prime candidate for reprogramming.

8.2 TECHNOLOGIES EVALUATED

8.2.1 Disk Drives

The major advantages of magnetic disk drives are high density, random access ability and radiation tolerance.The major disadvantages of magnetic drives are physical contact with the media and a greater predispostion to wear and tear than optical drives because of their mechanical parts. They also generate vibrations which could affect other parts of the SSF. Safeguarding the data from being over-written could be a problem, since hard drive write protection (on a sector by sector basis) is primarily software and firmware driven.

Optical drives are superior to magnetic disk drives in terms of density and lack of physical contact with the media. However, they also rely on mechanical components for the reading and tracking of the media. Although this technology is relatively new, there is a large amount of commericially available hardware. Of the three media utilized with an optical drive, the CDROM has the lowest power consumption since it does not have write capabilities. WORM has the next highest requirement for power (since it has write-once capabilities) and the rewriteable optical disks have the highest. Optical media can be prohibitively expensive with the rewriteable optical disks being the most expensive. Space-qualified units for the rewriteable disks are under development , but will not be available until 1997 at the earliest. These technologies will have tremendous potential for future space use and should be monitored periodically as improvements develop.

8.2.2 EEPROM Cartridge

EEPROM Cartridge technology has been successfully flown on several Space Lab missions and is currently being used by NASA Lewis on several programs; therefore, even though it has not been space-qualified, efforts have evidently been successful in obtaining waivers for that requirement. It excels in density, power, weight, access time, access method (random), writeability and ruggedness. It has no moving parts or any contact with the media. Even though storage capacities are only 40 Megabytes to 100 Megabytes, efforts are underway to improve the capacities. Weight and size of the cartridges are so small, that two could be installed to meet storage requirements, if necessary. Downloading software and data from the EEPROM cartridge would be as fast and reliable as RAM operations. As illustrated by the total score on the criteria evaluation form for this technology, the EEPROM cartridge has the best "fit" for on-orbit reprogramming of SSFF.

8.2.3 Tape Drive

Although tape drives are a proven technology and have a high density, the access method is sequential which makes the data transfer rate slower than most of the other technologies. Also the BER is slightly higher. This technology is better suited for massive data logging and retrieving rather than storage of individual programs where efficient location of files is required.

9. RESULTS AND RECOMMENDATIONS

The results and recommendations for the reprogramming study are outlined below.

1. After careful consideration of the selected concepts and technologies, the results indicate that use of the EEPROM cartridge as the non-volatile storage media would most closely fit the criteria and meet the storage requirements for the reprogramming task. The criteria evaluation for the EEPROM cartridge substantiates the recommendation of this trade study (See Table 5, Appendix A). As explained before, the EEPROM Cartridge technology has been successfully flown on several Space Lab missions and is currently being used by NASA Lewis on several programs. It excells in meeting most of the necessary criteria, contains no mechanical parts to wear down or break and has a write capability that will meet the SSFF reprogramming needs.

2. For reprogramming the SSFF on-orbit, it is recommended that an EEPROM cartridge be loaded with the necessary software and data and shipped to the SSF with each SSFF configuration. Minimal crew time would be required to install the cartridge into SSFF; it would be done much the same way as a floppy disk is inserted into a personal computer.

3. Unanticipated contingencies would be handled through uplink processes. With proper on ground verification and testing, these types of events should be extremely minimal.

10. REFERENCES

Specification sheets from:

1. Accura Innovative Services
   5511 Capital Center Drive, Suite 300
   Raleigh, NC 27606

2. Contemporary Cybernetics
   Newport News, VA

3. Dallas Digital Corp.
   Harrisburg, NC

4. Intel Corp.
   Santa Clara, CA

5. Targa Electronics Systems, Inc.
   San Ramon, CA

6. Ten X Technology, Inc.
   Austin, Texas

Other studies:

7. Foster, Mark A., "Commonality Study on Data System Items for a High Speed Data Handling System (Report)", McDonnell Douglas Space Systems Company, Space Station Division, March 1992.

APPENDIX A

CRITERIA EVALUATION TABLES

TABLE I. CDROM CRITERIA EVALUATION

A. CDROM					
	Target Values	Survey Data	Wt. Range Max.	Actual Weights	
Functional Capability:			30% total		
Storage capacity	200 Megabytes	1 Gigabyte	3.75	3.75	
Data transfer rate	1 Megabyte/sec	4 Megabyptes/sec	3.75	3.75	
Access method	Random Access	Random	3.75	3.75	
Support Circuitry required	Std. I/F	SCSI-2	3.75	3.75	
Ease of programming media (1 or 0)	1	0	3.75	0	
Write Capability (Modifiability)	Yes	No	3.75	0	
EDAC (Error Detection & Correction)	Yes	Yes	3.75	3.75	
BER (Bit Error Rate)	1 x 10 E12	1 x 10 E12	3.75	3.75	
Resource Requirements:			30% total		
Power consumption	10 Watts	35 Watts	6	1.74	
Weight	< 2.178 k (5 lbs.)	6.62 k (14.6 lbs.)	7	2.31	
Size	< 3277 cc (200 cu.in.)	9840 cc (600 cu. in.)	7	2.31	
Operating temperature	-50 to 100 deg C	10 to 40 deg C	4	0.8	
Crew Time for initial installation	< 5 min	4 min	6	6	
Maintainability:			20% total		
Durability/MTBF	> 40,000	20,000 hrs.	6.667	3.334	
Vibration, Non-operating	10 G	Not Available			
Shock, Non-operating	30G	25 G	6.667	3.334	
Transportability (1 to 10)	10	8	6.667	5.334	
Qualification Status:			10% total		
Ease of qualification (1 to 10)	10	8	5	4	
Space or Military qualification	Space	Neither	5	0	
Cost - Hdw, media & production	< $30 K	$ 42 K	10% total	7	
					TOTAL SCORE
					58.66

TABLE II. WORM CRITERIA EVALUATION

B. WORM					
	Target Values	Survey Data	Wt. Range Max.	Actual Weights	
Functional Capability:			30% total		
Storage capacity	200 Megabytes	940 Megabytes	3.75	3.75	
Data transfer rate	1 Megabyte/sec	5.55 Megabyptes/sec	3.75	3.75	
Access method	Random Access	Random	3.75	3.75	
Support Circuitry required	Std. I/F	SCSI-2	3.75	3.75	
Ease of programming media (1 or 0)	1	1	3.75	3.75	
Write Capability (Modifiability)	Yes	No	3.75	0	
EDAC (Error Detection & Correction)	Yes	Yes	3.75	3.75	
BER (Bit Error Rate)	1 x 10 E12	1 x 10 E12	3.75	3.75	
Resource Requirements:			30% total		
Power consumption	10 Watts	35 Watts	6	2.1	
Weight	< 2.178 k (5 lbs.)	6.62 k (14.6 lbs.)	7	2.31	
Size	< 3277 cc (200 cu.in.)	9840 cc (600 cu. in.)	7	2.31	
Operating temperature	-50 to 100 deg C	10 to 40 deg C	4	0.8	
Crew Time for initial installation	< 5 min	4 min	6	6	
Maintainability:			20% total		
Durability/MTBF	> 40,000	20,000 hrs.	6.667	3.334	
Vibration, Non-operating	10 G	Not Available			
Shock, Non-operating	30 G	20 G	6.667	4.467	
Transportability (1 to 10)	10	6	6.667	4	
Qualification Status:			10% total		
Ease of qualification (1 to 10)	10	8	5	4	
Space or Military qualification	Space	Military	5	2.5	
Cost - Hdw, media & production	< $30 K	$ 6 K	10% total	10	
					TOTAL SCORE
					68.071

TABLE III. REMOVABLE HARD DRIVE CRITERIA EVALUATION

C. Removable Hard Drive					
	Target Values	Survey Data	Wt. Range Max.	Actual Weights	
Functional Capability:			30% total		
Storage capacity	200 Megabytes	216 Megabytes	4.286	4.286	
Data transfer rate	1 Megabyte/sec	1 Megabyte/sec	4.286	4.286	
Access method	Random Access	Random	4.286	4.286	
Support Circuitry required	Std. I/F	SCSI	4.286	4.286	
Ease of programming media (1 or 0)	1	1	4.286	4.286	
Write Capability (Modifiability)	Yes	Yes	4.286	4.286	
EDAC (Error Detection & Correction)	Yes	Yes	4.286	4.286	
BER (Bit Error Rate)	1 x 10 E12	Not Applicable			
Resource Requirements:			30% total		
Power consumption	10 Watts	15 Watts	6	4.5	
Weight	< 2.178 k (5 lbs.)	1.995 k (4.4 lbs.)	7	7	
Size	< 3277 cc (200 cu. in.)	1931 cc (117.7 cu. in.)	7	7	
Operating temperature	-50 to 100 deg C	0 to 58 deg C	4	1.6	
Crew Time for initial installation	< 5 min	4 min	6	6	
Maintainability:			20% total		
Durability/MTBF	> 40,000	Not available			
Vibration, Non-operating	10 G	4 G	6.667	2.667	
Shock, Non-operating	30 G	30 G	6.667	6.667	
Transportability (1 to 10)	10	9	6.667	6	
Qualification Status:			10% total		
Ease of qualification (1 to 10)	10	Already qualified - 10	5	5	
Space or Military qualification	Space	Military	5	2.5	
Cost - Hdw, media & production	< $30 K	$ 14.7 K	10% total	10	
					TOTAL SCORE
					88.94

TABLE IV. OPTICAL DRIVE CRITERIA EVALUATION

D. Optical Drive	Target Values	Survey Data	Wt. Range Max.	Actual Weights	
Functional Capability:			30% total		
Storage capacity	200 Megabytes	1 Gigabyte	3.75	3.75	
Data transfer rate	1 Megabyte/sec	.68 Megabytes/sec	3.75	2.625	
Access method	Random Access	Random	3.75	3.75	
Support Circuitry required	Std. I/F	SCSI-2	3.75	3.75	
Ease of programming media (1 or 0)	1	1	3.75	3.75	
Write Capability (Modifiability)	Yes	Yes	3.75	3.75	
EDAC (Error Detection & Correction)	Yes	Yes	3.75	3.75	
BER (Bit Error Rate)	1 x 10 E12	< 1 block in 10 E14 bytes	3.75	3.75	
Resource Requirements:			30% total		
Power consumption	10 Watts	35 Watts	6	2.1	
Weight	< 2.178 k (5 lbs.)	8.62k (19 lbs.)	7	1.75	
Size	< 3200 cc (200 cu. in.)	9992.2 cc (609.2 cu. in.)	7	2.1	
Operating temperature	-50 to 100 deg C	5 to 51 deg C	4	1.32	
Crew Time for initial installation	< 5 min	4 min	6	6	
Maintainability:			20% total		
Durability/MTBF	> 40,000	40,000	6.667	6.667	
Vibration, Non-operating	10 G	24 G	6.667	3.334	
Shock, Non-operating	30 G	Not Available			
Transportability (1 to 10)	10	6	6.667	4	
Qualification Status:			10% total		
Ease of qualification (1 to 10)	10	8	5	4	
Space or Military qualification	Space	Military	5	2.5	
Cost- Hdw, media & production	< $30 K	$80 K	10% total	2.6	
					TOTAL SCORE
					65.25

TABLE V. EEPROM CARTRIDGE CRITERIA EVALUATION

E. EEPROM Cartridge					
	Target Values	Survey Data	Wt. Range Max.	Actual Weights	
Functional Capability:			30% total		
Storage capacity	200 Megabytes	100 Megabytes	3.75	1.875	
Data transfer rate	1 Megabyte/sec	1 Megabyte/sec	3.75	3.75	
Access method	Random Access	Random	3.75	3.75	
Support Circuitry required	Std. I/F	SCSI	3.75	3.75	
Ease of programming media (1 or 0)	1	1	3.75	3.75	
Write Capability (Modifiability)	Yes	Yes	3.75	3.75	
EDAC (Error Detection & Correction)	Yes	Yes	3.75	3.75	
BER (Bit Error Rate)	1 x 10 E12	10	3.75	3.75	
Resource Requirements:			30% total		
Power consumption	10 Watts	10 Watts	6	6	
Weight	< 2.178 k (5 lbs.)	1.47 k (3.25 lbs.)	7	7	
Size	< 3277 cc (200 cu. in.)	1517 cc (92.6 cu. in.)	7	7	
Operating temperature	-50 to 100 deg C	-40 to 85 deg C	4	4	
Crew Time for initial installation	< 5 min	4 min.	6	6	
Maintainability:			20% total		
Durability/MTBF	> 40,000	70,000 hrs	5	5	
Vibration, Non-operating	10 G	10G	5	5	
Shock, Non-operating	30 G	30G	5	5	
Transportability (1 to 10)	10	9	5	4.5	
Qualification Status:			10% total		
Ease of qualification (1 to 10)	10	9	5	4.5	
Space or Military qualification	Space	Ruggedized military	5	2.5	
Cost- Hdw, media & production	< $30 K	$18 K	10% total	10	
					TOTAL SCORE
					94.63

TABLE VI. TAPE DRIVE CRITERIA EVALUATION

F. Tape Drive	Target Values	Survey Data	Wt. Range Max.	Actual Weights	
Functional Capability:			30% total		
Storage capacity	200 Megabytes	2-8 Gigabytes	3.75	3.75	
Data transfer rate	1 Megabyte/sec	.78 Megabytes/sec	3.75	2.925	
Access method	Random Access	Sequential	3.75	0	
Support Circuitry required	Std. I/F	SCSI-2	3.75	3.75	
Ease of programming media (1 or 0)	1	1	3.75	3.75	
Write Capability (Modifiability)	Yes	Yes	3.75	3.75	
EDAC (Error Detection & Correction)	Yes	Yes	3.75	3.75	
BER (Bit Error Rate)	1 x 10 E12	1 x 10 E9	3.75	3.563	
Resource Requirements:			30% total		
Power consumption	10 Watts	15 Watts	6	4.02	
Weight	< 2.178 k (5 lbs.)	2.2k (4.8 lbs.)	7	7	
Size	< 3200 cc (200 cu. in.)	631.9 cc (38.5 cu. in.)	7	7	
Operating temperature	-50 to 100 deg C	15 to 35 deg C	4	0.52	
Crew Time for initial installation	< 5 min	4 min	6	6	
Maintainability:			20% total		
Durability/MTBF	> 40,000	50,000 hrs.	5	5	
Vibration, Non-operating	10 G	1 G	5	0.5	
Shock, Non-operating	30 G	1 G	5	0.5	
Transportability (1 to 10)	10	8	5	4	
Qualification Status:			10% total		
Ease of qualification (1 to 10)	10	5	5	2.5	
Space or Military qualification	Space	Neither	5	0	
Cost- Hdw, media & production	< $30 K	$5.3 K	10% total	10	
					TOTAL SCORE
					72.28

SSFF-VTR-001

TECHNICAL REPORT

SPACE STATION FURNACE FACILITY VENTING REQUIREMENTS TASK

September 1991
Space Programs Division
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Acronym/Abbreviation List

AADSF	Advanced Automated Directional Solidification Furnace
ARS	Air Revitalization System
CEI	Critical End Item
CGF	Crystal Growth Furnace
EAC	Experiment Apparatus Container
ECLSS	Environmental Control/Life Support Systems
ESA	European Space Agency
IFEA	Integrated Furnace Experiment Assembly
FTIR	Fourier Transform Infra-Red
GC	Gas Chromotography
GCEL	Ground Control Experiment Laboratory
GCRU	Gaseous Contaminant Removal Unit
GPWS	General Purpose Workstation
GTE	General Telephone and Electronics
IECM	Induced Environmental Contamination Monitor
MAC	Maximum Allowable Concentration
MS	Mass Spectroscopy
MSFC	Marshall Space Flight Center (NASA)
MSG	Material Science Glovebox
NASA	National Air and Space Agency
PI	Principal Investigator
RPI	Rensaeler Polytechnic Institute
SACA	Sample Ampoule Cartridge Assembly
SAE	Society of Automotive Engineers
SEAS	South Eastern Analytical Services
SMAC	Spacelab Maximum Allowable Concentration
SPAH	Spacelab Payload Accommodations Handbook
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TCCS	Thermal Control and Conditioning System
TMC	Technical Micronics Control, Inc.
VS1	Vacuum System 1 (SSF)
VS2	Vacuum System 2 (SSF)

FOREWORD

This study was performed by Teledyne Brown Engineering under contract to NASA's Marshall Space Flight Center. Principal contributors to the study and this report are Mr. John Chan, Mr. Jerry LeCroy, and Mr. Jose Liwag. The authors wish to express their appreciation to all of the CGF and AADSF team members who assisted in the collection of material samples during test operations, and especially to Mr. Coffee and Mr. Hand, of TBE, and Mr. Cole, of MSFC.

1.0 SCOPE

The scope of work for this study is to develop realistic venting requirements for the Space Station Furnace Facility (SSFF), based on data obtained from current and planned furnace experiments and on space station service capabilities. The results of this study may be used as input to interface control documents defining functional interfaces between the core SSFF, the station services, and the experiment modules.

This study obtained data, by research and by taking physical samples from Advanced Automated Directional Solidification Furnace (AADSF) and Crystal Growth Furnace (CGF) microgravity experiment furnaces, to determine what vent rates and effluent components might be vented from candidate experiments to be flown with the SSFF on Space Station Freedom (SSF)

2.0 EXECUTIVE SUMMARY

In this study analyses were performed on constituents of gases vented from the AADSF and CGF furnace experiments during ground testing. Research was performed on possible contaminant materials and quantities which could reasonably be expected to be produced during on-orbit operations of the SSFF. The results were used to develop recommendations for the interface requirements between the furnace facility and both the furnace experiments and the station services.

In general, vent products exhausted from materials processing experiments during normal operations are expected to be benign, and to be produced at a relatively low volumetric rate. Very few gas samples taken from experiments during ground testing exceeded any Spacelab Maximum Allowable Concentration (SMAC) values for the cabin atmosphere. All exceedances observed were limited to hydrocarbons believed to be from cleaning solvents which were used on the experiment hardware.

The major issue in the design of the SSFF venting system is the handling of off-nominal vent products resulting from sample containment failure, coolant leak, or other failure conditions within the experiment payloads. In the event of a sample containment failure, contaminant levels may exceed SMAC levels significantly, and potentially hazardous materials could be released into the SSF vent system.

The findings of this study support our recommendation that the SSF adopt an approach that will permit venting of furnace effluents. First, the interface between the furnace facility and the Space Station Freedom (SSF) vacuum service connection should be specified to permit routine venting of experiment fill gasses whose contaminant levels generally fall within SMAC levels for the cabin atmosphere. Second, the SSF should make allowances to permit single-event venting of furnace atmospheres which have been contaminated to saturation vapor pressure levels with investigator sample materials. The Space Station Freedom vacuum service user interface should tolerate these single-event exceedances at least once each service period during the man-tended phase. Any contaminants evolved during experiment operations could be vented overboard during manned operations for sample change-out.

No basic incompatibility exists between the SSFF venting requirements for nominal operations and the expected allowable venting limits for SSF payload elements. This study compared the venting requirements derived from the furnace experiments found to be likely SSFF payloads to the limitations likely to be imposed on the SSFF by the SSF, vent utility system. In general, no violations of strict SSF compatibility guidelines are expected during any nominal SSFF operations. Single-event exceptions to vent system restrictions may occur during anomalous operations.

Venting of furnace effluents is also recommended to simplify the furnace facility venting system and to permit a return to service of furnaces which might have been contaminated by sample containment failures. This approach avoids the mechanical complexity, cost, and weight of vent gas compression and containment devices, and the failure detection systems necessary to determine the quantity and constituents of any vent gas mixture. At the same time, the necessity for returning otherwise functional furnaces to earth for decontamination will be eliminated, improving science return while reducing life cycle cost.

3.0 VENTING ANALYSIS TASKS

The object of the study is to identify the materials that are evolved during the operation of the Crystal Growth Furnace (CGF) and Advanced Automated Directional Solidification Furnace (AADSF) to analyze those materials which could contaminate the furnace gas atmosphere. From the results of these analyses, suggestions and guidelines are provided for the proper selection of materials and equipment to be used in the design of the furnace venting facilities and handling of furnace gas effluents in the Space Station Freedom (SSF).

Waste gas products and sources were analyzed to determine the constituents and quantities of possible contaminants which would enter the SSFF vent system and thence the Space Station Freedom vacuum service system. These analyses focused on the Advanced Automated Directional Solidification Furnace (AADSF) and the Crystal Growth Furnace (CGF), both are materials processing experiments and typical of SSF materials processing experiments. Additional study was performed to determine normal processing experience in ground-based (commercial) crystal growth facilities.

The crystal growth experiments involve the growing of semiconductor or electronic material crystals using vapor crystal growth and directional solidification in the CGF Furnace and the AADSF with research grade or high purity argon gas atmosphere.

Preparatory to the CGF furnace test runs the Experimental Apparatus Container (EAC) is evacuated or vented to 0.5 psia for 20 minutes and then it is backfilled with argon gas to 10 psia. This cycle is repeated, except the argon gas backfill pressure is kept at 13.5 psia before the EAC cover is opened. The Sample Ampoule Cartridge Assembly (SACA) with the crystal growth sample material is then placed inside the furnace. The EAC cover is closed and sealed, then leak tests are performed and the foregoing venting and backfilling cycles are repeated, except the final argon gas atmosphere backfill pressure is kept at 10 psia, which is a negative gage pressure. (Unlike the CGF, the AADSF furnace is operated at 18/19 psia.) The furnace heaters are then turned on and the crystal growth experiment process furnace time-temperature profile/cycle (or time line) is started. It was during this processing regime that gas samples were taken to determine the makeup of vent gas during nominal operations.

3.1 Analysis of Possible Waste Gas Products

The first task in the venting requirement analysis study was to determine the types of experiments likely to be supported by the SSFF. The CGF and AADSF material processing furnaces are typical of the experiments to be operated with the SSFF. These experiment systems, developed by Teledyne Brown Engineering under Marshall Space Flight Center contracts, were in ground control experiment laboratory (GCEL) testing during the performance of this study. As such, they were chosen as valid specimens for deriving SSFF experiment interface requirements for vent systems.

Samples of the inert gas (argon) atmosphere inside the furnace container and of particulates filtered from the vent gas stream were analyzed to determine the types and levels of contaminants produced during extended ground testing. Figure 3-1 illustrates the test sample configuration. With each set of gas samples drawn from an operating furnace, a reference sample was taken from the pressurant source used to fill the experiment apparatus. This permitted differential analysis of the contaminants which were added to the container atmosphere during processing. Several samples were taken at different temperature set-points for both AADSF and CGF furnaces. Samples collected were sent to independent laboratories for physical and chemical analysis.

The Gas Chromatography Mass Spectroscopy method was used to analyze gas samples for oxygen content and inorganic and organic gas contamination. Energy Dispersive X-ray analysis was used to identify the particulates collected on filter paper. These chemical analysis results were later evaluated by material engineers to determine the levels and the sources of identified contaminants.

The following sections describe the intent and method applied to analysis of gas samples from the CGF and AADSF furnaces. A summary of the chemical analysis results for samples taken during the CGF Principal Investigator (PI) test runs is included in Appendix C.

3.1.1 CGF Samples Analysis

Argon gas and filtrate samples were taken from a number of tests runs performed with the CGF flight and ground units. Table 3-1 lists some of the CGF test run conditions. A chemical analysis summary which lists the conditions under which the samples were taken can be found in Appendix C of this report.

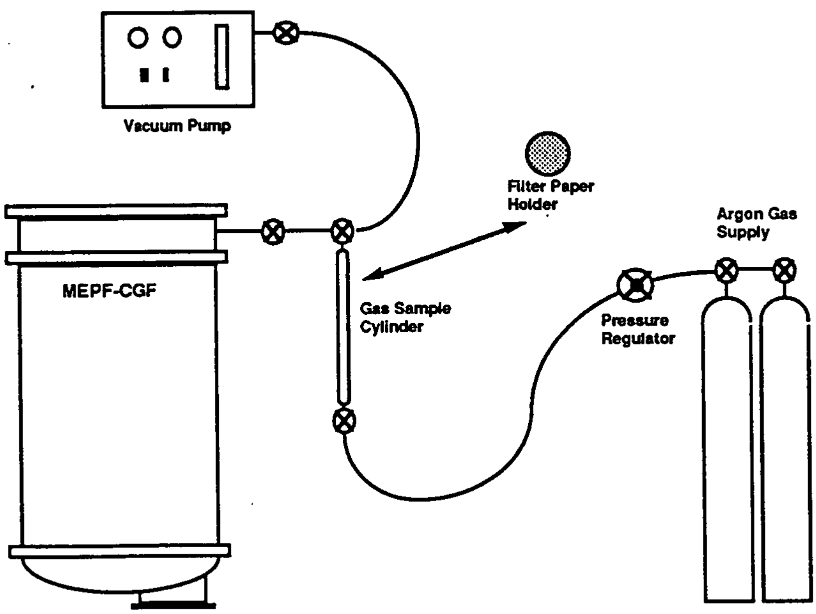

Figure 3-1 Test Sampling Equipment Configuration

Test Description	SACA Configuration	RFM Temp. (°C)	Test Duration (Hr)	Samples Taken
MSFC Science Run #2	Hg Zn Te* Sample Inconel Cartridge	HZ - 802 CZ - 375	161:00	2 Argon Gases 3 Filter Paper
GTE Thermal Probe Run #1	No Sample Dummy Alumina	HZ - 1260 CZ - 1230	25:00	3 Argon Gases 1 Filter Paper
RPI-7 Science Run #3	Hg CdTe* Sample Inconel Cartridge	HZ - 625 CZ - 455	19:00	3 Argon Gases 1 Filter Paper
MSFC Science Run #3	Hg Zn Te* Sample Inconel Cartridge	HZ - 780 CZ - 350	160:00	3 Argon Gases 1 Filter Paper
Grumman Science Run #3	Cd Te Sample* TZM Cartridge**	HZ - 1175 CZ - 980	98:00	3 Argon Gases 1 Filter
RPI-8 Science Run #4	Hg CdTe* Sample Inconel Cartridge	HZ - 625 CZ - 455	18:45	2 Argon Gases 1 Filter Paper
GTE Science Run #1	Ga Sa Sample* TZM Cartridge	HZ - 1260 CZ - 1230	26:00	2 Argon Gases 1 Filter Paper

*Mercury Cadmium Telluride (HgCdTe) with mercury iodide as transport agent; Gallium-Selenium doped Arsenide (GaAs); Cadmium-Zinc doped Telluride (CdTe); Mercury Zinc Telluride (HgZnTe

** Molybdenum TZM alloy

Table 3-1 CGF Test Conditions

3.1.2 AADSF Samples Analysis

Gas samples were also collected from the AADSF furnace and analyzed.

3.2 Results of Chemical Analyses

3.2.1 CGF Samples

The results of the gas sample chemical analysis for the CGF furnace showed negligible amounts of oxygen. No inorganic gaseous contaminants were detected in the samples. All gaseous organic analyses showed various organic compounds detected were below the Maximum Allowable Concentration (MAC) limit requirements, (NHB 8060.1B), except for two anomalous results found for total hydrocarbon levels in samples taken during the RPI-7 and the GTE-1 test runs.

Three argon gas samples were taken during the RPI-7 test run. The first sample taken indicated a relatively high concentration of hydrocarbons (18.4 ppm). The other two samples indicated concentrations of less then 5.0 ppm. Contamination was suspected due to the variance between subsequent sample results. To test the sample contamination theory, additional samples were taken during an identical test run, RPI-8. The maximum hydrocarbon concentrations found in samples from this test run was 1.3 ppm, supporting the sample contamination hypothesis.

One additional set of samples appeared to suffer from handling errors. The chemical analysis results for the gas sample taken during GTE-1 test run appeared to be contaminated with room air, due to errors in sample handling. (See TMC Chemical Analysis Report #21096.) The EAC negative gage pressure used during CGF experiments was believed to be the major contributor to the sampling errors noted. Errors in sample handling would likely lead to contamination with ambient air.

Table 3-2 summarizes the chemical composition of the contaminants in the argon gas samples taken during the testing of the CGF furnace.

CGF TEST RUNS	OXYGEN CONTENT	GASEOUS ORGANIC CONSTITUENTS					
	%	Methane (CH4) ppm	Carbon Monoxide (CO) ppm	Carbon Dioxide (CO_2) ppm	Total Hydro-carbon (HC) ppm	Total Halo-genated Hydro-carbon (HHC) ppm	FTIR** Scan
MAC[1]		2700	25	10,000	7.5		
MSFC	< 0.01	0.8/< 5.0	< 5.0	14.5/20.0	1.9/2.3	0.56/1.0	ND[+]
Argon Ref.	< 0.01	< 5.0	< 5.0	54.3	3.5	0.91	Used as ref.
RPI-7	.02/.06	1.75/2.9	<5	123/125	< 5/18.4	< 1/2.0	CO_2 Freon 12 Freon 13 Freon 113
Grum-man 7	< 0.01	< 5.0	< 5.0	8.4	1.35	< 1.0	Trace CO_2
Argon Ref.		2.1	< 5.0	2.3	1.2	< 1.0	Used as ref.
RPI-8	< 0.01	< 5.0	< 5.0	8.4	1.3	0.10	Trace Tri-chloro-ethylene
Argon Ref.	< 0.01	< 5.0	< 5.0	4.1	0.7	0.2	
GTE	1.9	5.1	< 5.0	5.2	6.6	1.5	ND[+]
Bakeout	0.13	2.9	< 5.0	101.0	11.7	1.4	CO_2
AADSF TEST RUNS							
Argon Ref	< 0.01%	< 5.0	< 5.0	< 1.51	6.85	< 1.00	Ref
Verifi-cation Profile	< 0.01%	15.9	111	50.4	57.6	3.99	Trace Tri-chloro-ethylene
Thermal Cycle No. 9	< 0.01%	24	735	382	58.0	.007	ND[+]

1 Maximum Allowable Concentration

** Fourier Transform Infra-Red

\+ None Detected

Table 3-2 Gas Samples Analyses Results for CGF and AADSF

Results of the filtered gas effluents are listed in Table 3-3. Chemical analysis on these filter papers identify only the particulates in the gas samples. Determination of particle quantity and size distributions was not possible, due to the limited number of particles collected in each sample. As a rule, each filter sample had a few tens of particles, mostly in the 10 micron size range.

The sulfur reported in the analysis of particulates is felt to be due to molybdenum levels, and does not reflect actual sulphur content of the furnace effluent. The analysis tools used for this purpose were unable to distinguish between sulphur and molybdenum particles. The element found is assumed to be molybdenum because no significant source for sulphur contamination exists in the hardware tested.

3.2.2 AADSF Samples Analyses Results

The result of the analysis of the AADSF furnace gas effluents showed negligible amounts of oxygen, at <0.01% oxygen. Analysis of the two AADSF furnace gas effluent samples showed the gaseous organic contaminants were within the MAC limit requirements, except for carbon monoxide and the total hydrocarbon levels. The MAC limits for carbon monoxide (CO) and total hydrocarbons are 25 ppm and 7.5 ppm, respectively. The results of the analysis of two AADSF furnace gas effluent samples showed 777 ppm and 735 ppm carbon monoxide and 57.6 ppm and 58.0 ppm total hydrocarbon content.

No gaseous inorganic contaminants were detected in the analysis of the AADSF furnace gas effluents.

The result of the analysis of the particulate sample taken from the AADSF thermal cycle No. 9 test run showed the presence of iron, silicon, calcium, and phosphorus, all at very low levels. Significantly, no alumina or beryllia were detected in the particulate analysis.

CGF	CONSTITUENTS MAJOR	CONSTITUENTS TRACE ELEMENT
MSFC Science Run #2	From SEAS: Silicon (Si), Zinc (Zn), Oxygen (O) From MSFC M&P Lab.: Iron (Fe), Zinc (Zn), Chromium (Cr), Nickel (Ni), Calcium (Ca), Titanium (Ti) From Trimet Inc.: Silicon (Si)	From SEAS: Phosphorus (P), Sulfur[1] (S), Potassium (K) From MSFC M&P Lab.: Aluminum (Al), Potassium (K), Copper (Cu), Silicon (Si), Manganese (Mn), Sulfur (S), Chromium (Cr), Iron (Fe)
GTE TP Run #1	Silicon (S)	
RPI-7 Science Run #3	Molybdenum (Mo), Chlorine (Cl), Potassium (K)	Possible Trace of Niobium. But with a Chi factor of 0.71
MSFC Science Run #3	Silicon (Si)	Possible Trace of Niobium (Nb). If Nb is present, the amount would be very small.
RPI-8 Science Run #4	Molybdenum (Mo) Silicon (S) Iron (Fe)	Large scattered particles: Silicon (S), Iron (Fe), Chromium (Cr), Nickel (Ni)
GTE Science Run #1	Silicon (Si), Chlorine (Cl), Niobium(Nb). Small scattered particles were visible all over the sample - Sodium (Na), Iron (Fe)	Found in small scatter particulates - Magnesium (Mg), Silicon (Si), Sulfur (S), Chlorine (Cl), Potassium (K), Calcium (Ca), Titanium (Ti)
AADSF		
Thermal Cycle No. 9	Phosphorus (P), Iron (Fe), Silicon (Si), Calcium (Ca)	

Table 3-3 Filter Samples Analyses Results for CGF and AADSF

3.3 Results and conclusions from venting product study

Most gas contaminants found in the CGF and AADSF vent gas streams were below the MAC levels acceptable for the shuttle cabin atmosphere. Particulate counts were very low, and in general were below those noted for the cabin atmosphere during normal shuttle operations. It is expected that these particulate counts will be higher, however, for on-orbit operations. Higher values will occur on-orbit due to the absence of gravity-induced particulate settling.

The materials processing furnaces, in normal operations, should be compatible with the SSF venting system resource requirements. The second phase of this study is an analysis of possible contaminant sources in the experiments which might produce compatibility problems during off-nominal operations.

3.4 Recommendations

No specific gas processing is recommended for the SSFF facility vent system in nominal operations. Particulate filtering might be recommended for the facility if inert gas is to be conserved by storing and reusing pressurant in the SSFF. This filtering will prevent a buildup of solid contaminants within the experiment containers. These filters, if incorporated into the SSFF system, should have a high collection efficiency for particles as small as 0.4 microns. The filter materials should be stable for vacuum operations, and should not outgas excessively during nominal exposure to thermal-vacuum testing. One filter material candidate is porous silica, commercially produced as a high purity filter media. Porous silica media is available which produces high capture ratios for particles as small as 0.3 microns.

4.0 ANALYSIS OF FURNACE GAS CONTAMINATION SOURCES

4.1 Description of Analysis

This section describes the possible sources of contamination from within the SSFF experiments, based on furnace and sample materials constituents and operating conditions.

4.1.1 CGF and AADSF

The various elements detected in the analyses are listed below showing the corresponding probable sources within the CGF Integrated Furnace Experiment Assembly (IFEA) and AADSF experiment apparatus containers (EAC's) .

Table 4-1, Possible Sources of Contamination, shows the various elements and compounds evolved during the test runs conducted in the CGF and AADSF furnace systems. None of the contaminants observed appears to represent a safety or compatibility hazard.

4.1.2 Science Sample Containment

The molybdenum cartridge used on some principal investigator (PI) samples was found to be a major source of contamination in the CGF furnace. Molybdenum oxidizes rapidly at high temperature with even trace oxygen concentrations. Other cartridge materials which have been proposed are alumina, inconel, 304 stainless steel, and platinum. None of these materials places significant performance burdens on the SSFF vent system.

4.1.3 Contaminant Sources in Ground Furnaces

A survey of industrial materials processing operations was performed, questioning industrial and scientific laboratories concerning their methods for handling hazardous effluents. The Environmental Protection Agency and OSHA were also contacted in order to gather guidelines by which these systems should be designed in order to prevent venting any hazardous materials into the environment. In general, industrial materials processors consider their processes and waste gas handling procedures to be competition-sensitive, and were unwilling to disclose data for publication. EPA and OSHA representatives were also unwilling to divulge data on vent releases from specific processors, though this material might be provided in response to a Freedom of Information Act disclosure request.

4.1.4 Non-Furnace On-Orbit Contaminant Sources

Teledyne Brown Engineering submitted four Engineering Change Requests to the IML-1, USML-1, SL-J, and SL-D2 Spacelab Mission Managers. Mr. Arthur S. Kirkindall/MSFC PPO included a cover letter which explained the background for submission of the ECR's. These ECR's will be submitted into a Configuration Control Board for baselining into the Ground Operations Procedures of the above missions.

4.2 Results of Analysis

Materials used in the CGF and AADSF are listed in the Material Inventory List in Appendix G and H of this report. Also, the Material Identification and Usage List (MIUL) for CGF and AADSF can also be found in the Appendices.

PARTICULATES FOUND IN FILTER PAPER	SOURCES
Aluminum	From components made of aluminum alloys, from alumina bearing insulation, alumina ceramic, aluminum bronze and other aluminum bearing parts
Iron, Chromium, Nickel, Manganese	From components made of steels such as stainless, carbon or alloy steels. Also, parts that are chromium or nickel plated
Copper, Zinc, Phosphorus, Lead	From components such as phosphor bronze, brass, electrical wire, cables, solder, electroplating, zinc bearing components, P.I. test samples, silicon rubber, silicon lubricants, etc.
Silicon	From components made from silica (glass) such as fiberglass insulation, glass ampoule, ceramic insulation, etc.
Titanium	From SEM Arm Assembly, Support and other components made of titanium alloys. Also, filler for paints, ceramic, etc.
Molybdenum	From TZM, Inconel and molybdenum cartridges. Also, components made of steel alloys, etc.
Calcium, Chlorine, Potassium, Sodium, Sulfur[1]	From components made of non-metallic materials, such as adhesives, coatings, plastics, ceramics, elastomers, rubber, lubricants, also sulfur from 303 s/s
Magnesium	From contaminants in ceramic insulation, possibly also as constituents in non-metallic materials
Niobium[2]	From components made of stainless steels, such as Cres 347

1. Sulfur findings were ambiguous
2. Trace levels only

Table 4-1 Possible Sources of Contamination

4.3 Results and Conclusions

The only significant hazardous material issues for the SSFF vent system stem from the toxic or otherwise hazardous science samples being processed. Secondary concerns involve the beryllia and other ceramic oxides used in the construction of high temperature furnaces, but these materials are felt to be mechanically and chemically stable, and unlikely to be vented in significant amounts.

4.4 Recommendations

The SSFF vent system as currently designed is believed to be capable of tolerating any of the identified potential waste gas constituents without degradation. In general the most difficult part of the materials compatibility definition is defining those PI materials to which the SSFF may be exposed. Two options, discussed at greater length in section 5, are for the experimenters to provide pre-filters on the furnace experiments designed to stop known sample constituents, and to develop a catalog of known science sample materials.

5.0 DESIGN OPTIONS

This section covers the design options considered for handling the vented gas stream from a typical SSFF furnace experiment. This section will first address the requirements for a SSFF vent gas system. Then, several design options are discussed to meet these requirements. Finally, SSF recommendations are made concerning the Space Station Freedom and the Space Station Furnace Facility SSFF Venting Systems and their interface requirements.

5.1. SSFF Venting Requirements

5.1.1. SSFF-Derived Design Requirements

The SSFF venting requirements have been determined from the March 8, 1990 draft of the SSFF Capability Requirements Document. The most significant requirements are listed below.

1. Minimum/Maximum gas flows are TBD (page 9, ref 6)

2. A vacuum level of 10-5 torr is required (page 9, ref 6)

3. Overboard venting will have a 1 x 10-3 torr maximum pressure. (page 9, ref 6)

4. Furnace experiment containers will have pressure control ranging from 0.1 to 1.0 atmosphere. (page 10, ref 6) For safety reasons involving redundancy of containment, the furnace experiments are likely to operate below the cabin air pressure (approximately 10 to 14.7 psia). Some experimenters may wish to operate in rarified (<1 torr) or reducing (hydrogen) atmospheres.

5. Active cooling for low temperature zones. (page 11, ref 6) Use of SSFF-supplied gases for quenching is a good possibility. Some experiments may require spraying water or other liquids for quenching. The use of liquids for active cooling is not considered a SSFF baseline requirement. Dispensing free liquids into the furnace container at high operating temperatures would be a significant design and safety impact on the SSFF venting system.

6. Process waste gas from SSFF after purging the furnace container. Gases are used by the SSFF to:

   Minimize oxygen content in the furnace environment.
   Purge used waste gases from the furnace cavity.
   Provide pressure control for material processing.
   Provide active cooling if required by attached material processing experiments.

7. Manual sample material change out at regular intervals.

8. The SSFF must permit rack rotation away from the SSF wall within one minute for quick wall repairs.

5.1.2. SSF Derived Design Requirements

The Space Station Freedom vacuum vent interface requirements are largely derived from the Laboratory Vacuum Subsystem Envelope Drawing prepared by Boeing, document number 683-18005. Selected portions of this document can be found in Appendix B. These design requirements are summarized below.

1. Overboard venting to 1 x 10^{-3} torr maximum pressure.

2. Two vent systems are available for venting to space, however, only one can be used at a time. In addition, the control for these vacuum vent lines is provided by the SSF Command and Control Software. This external control of the vacuum vent line will complicate SSFF requirements for pressure control and contingency venting. The high pressure vacuum vent system is called the VS1 and is used for general venting or gas volume purging (> 10^{-3} torr). The lower pressure (higher quality) vacuum vent system, VS2, is used only for vacuum maintenance (10^{-3} torr maximum, no venting allowed beyond "normal outgassing").

3. The VS1 gas throughput is 2.3 x 10^{-3} torr-liter/sec maximum at 1 x 10^{-3} torr (based on nitrogen at 22 °C)

4. Only non-toxic waste gases are allowed to be vented into the SSF vacuum vent system. These gases are:

Nitrogen
Air
Argon
Krypton
Xenon
Helium
Carbon Monoxide (maximum 50 ppm at atmospheric pressure)
Carbon Dioxide (partial pressure not greater than ambient)
Mixtures of these gases
Limited amounts of oxygen and hydrogen (less than 4% at 0.001 torr)
Trace gases (see Table 5-1)

5. Allowable Vent Contaminates are derived from the vacuum system envelope drawing and Spacelab Payload Accommodations Handbook (SPAH).

A comparison between the allowable SSF vacuum vent contaminates and the Spacelab Maximum Allowable Concentrations (SMAC) allowed on the Space Shuttle shows that in most cases the vacuum vent requirements are more restrictive. If the current vacuum vent requirements are not modified, it is possible that venting cabin air will be prohibited. The SMAC ranges shown in Table 5-1 are only for comparison purposes. More detailed SMAC listings are provided in Appendix D.

5.1.3 Results from AADSF and CGF testing.

A summary of gas test samples from two candidate SSFF is provided in the following Table 5. The Advanced Automated Direction Solidification furnace (AADSF) and the Crystal Growth Furnace (CGF) are two furnaces that TBE has developed under MSFC contract for Space Shuttle materials processing. Due to the maturity of these two furnace designs, both are considered good candidates for SSFF development. More detailed information about testing procedures, test results and furnace materials can be found in section 2 of this report.

A comparison between tables 5-1 and 5-2 shows that for normal material processing, the two furnaces produce relatively benign waste gases. Except for carbon monoxide and total hydrocarbons, the furnaces would fall below the crew cabin maximum allowable concentration (MAC) limits. While venting of furnace waste gases into the cabin atmosphere is not a planned activity, this observation reflects the innocuous nature of furnace venting during normal operations.

RACK INTERFACE CHARACTERISTIC	SSF INTERFACE LIMIT (PPM, MAX)	SPAH MAC levels for 7 day missions (PPM)
Acids		
- Organic	5	1 to 25
- Inorganic	5	0.3 to 1
Bases		
- Organic	5	
- Ammonia	5	25
- Inorganic	5	
Halogens (C12, F2, Br2, I2)	5	
Particulates		
0.0005% by volume for particles >10 microns		280- 300 micron filters used on Spacelab
Organic Classes		
- Gases	5	
- Solvents	5	
- Organohalides		
- Hydrocarbons		15 to 1500
- Aromatic Hydrocarbon		0.1 to 30
- Alcohols, Ethers, Esters		0.5 to 40
- Ketones, Aldehyde, Amides		0.1 to 300
- Misc. (Thiols, Sulfides, Nitriles)		0.1 to 5.0
Specific Materials		
- Inorganic	5	
-- H_2S, SO_2, Hg		1
- Organic	5	
- CH_2O, C_6H_6		
- HCN		1
Carbon monoxide	50	25
Methane	5	2700

Table 5-1. SPAH and SSF Contaminate Allowables

CGF TEST RUNS	OXYGEN CONTENT %	GASEOUS ORGANIC CONSTITUENTS* Methane (CH_4) ppm	Carbon Monoxide (CO) ppm	Carbon Dioxide (CO_2) ppm	Total Hydro-carbon (HC) ppm	Total Halo-genated Hydro-carbon (HHC) ppm	FTIR** Scan
MAC[1]		2700	25	10,000	7.5		
MSFC	< 0.01	0.8/< 5.0	< 5.0	14.5/20.0	1.9/2.3	0.56/1.0	ND+
Argon Ref.	< 0.01	< 5.0	< 5.0	54.3	3.5	0.91	Used as ref.
RPI-7	.02/.06	1.75/2.9	<5	123/125	< 5/18.4	< 1/2.0	CO_2 Freon 12 Freon 13 Freon 113
Grumman 7	< 0.01	< 5.0	< 5.0	8.4	1.35	< 1.0	Trace CO_2
Argon Ref.		2.1	< 5.0	2.3	1.2	< 1.0	Used as ref.
RPI-8	< 0.01	< 5.0	< 5.0	8.4	1.3	0.10	Trace Trichloro ethylene
Argon Ref.	< 0.01	< 5.0	< 5.0	4.1	0.7	0.2	
GTE	1.9	5.1	< 5.0	5.2	6.6	1.5	ND+
Bakeout	0.13	2.9	< 5.0	101.0	11.7	1.4	CO_2
AADSF TEST RUNS							
Argon Ref	< 0.01%	<5	< 5.0	< 1.51	6.85	< 1.00	Ref
Verifica-tion Profile	< 0.01%	15.9	111	50.4	57.6	3.99	Trace Trichloro ethylene
Thermal Cycle No. 9	< 0.01%	24	735	382	58.0	.007	ND+

[1]Maximum Allowable Concentration. Sources: NASA HDBK 8060.1B - Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion, and NASA Memo SD4/84-382, Initiator SD4/M. E. Coleman, JSC.

* Gas Chromatography (GC) and Mass Spectroscopy (MS)

** Fourier Transform Infrared

+None Detected.

Table 5-2 AADSF and CGF Test Results

The initial operation of the AADSF and CGF type furnaces will also output a small amount of dust produced by the shuttle launch vibrational environment. After vibration testing, both furnaces have shown visible signs of dust particles. This dust is produced by the interaction between various ceramic, metallic and fibrous furnace components. Testing of these small particles was attempted from the available gas samples and sample wipes of the interior surfaces. A particulate size survey was unable to obtain sufficient particles for meaningful statistical analysis. At this time we must assume that the furnaces will not meet the vacuum vent solid particle requirements. However, from the type of cabin air filters listed in SPAH (pg C4-30) for Spacelab missions (300 micron absolute), the normal Space Shuttle cabin air environments will also not meet the restrictive SSF vacuum vent interface requirements.

For comparison purposes, the 10 micron size listed in the SSF vacuum vent requirements is marked in Figures 5-1 and 5-2. Figure 5-1 shows size ranges for a variety of common airborne materials. Figure 5-2 compares the contaminant sizes relative to several common filter techniques. In general, space-borne atmosphere contain much higher particulate levels, since particle settling does not occur in the micro-gravity environment. This comparison suggests that the SSF restrictions on particulates may be relaxed. Under the present limits, cabin air is likely to require filtering prior to overboard vent.

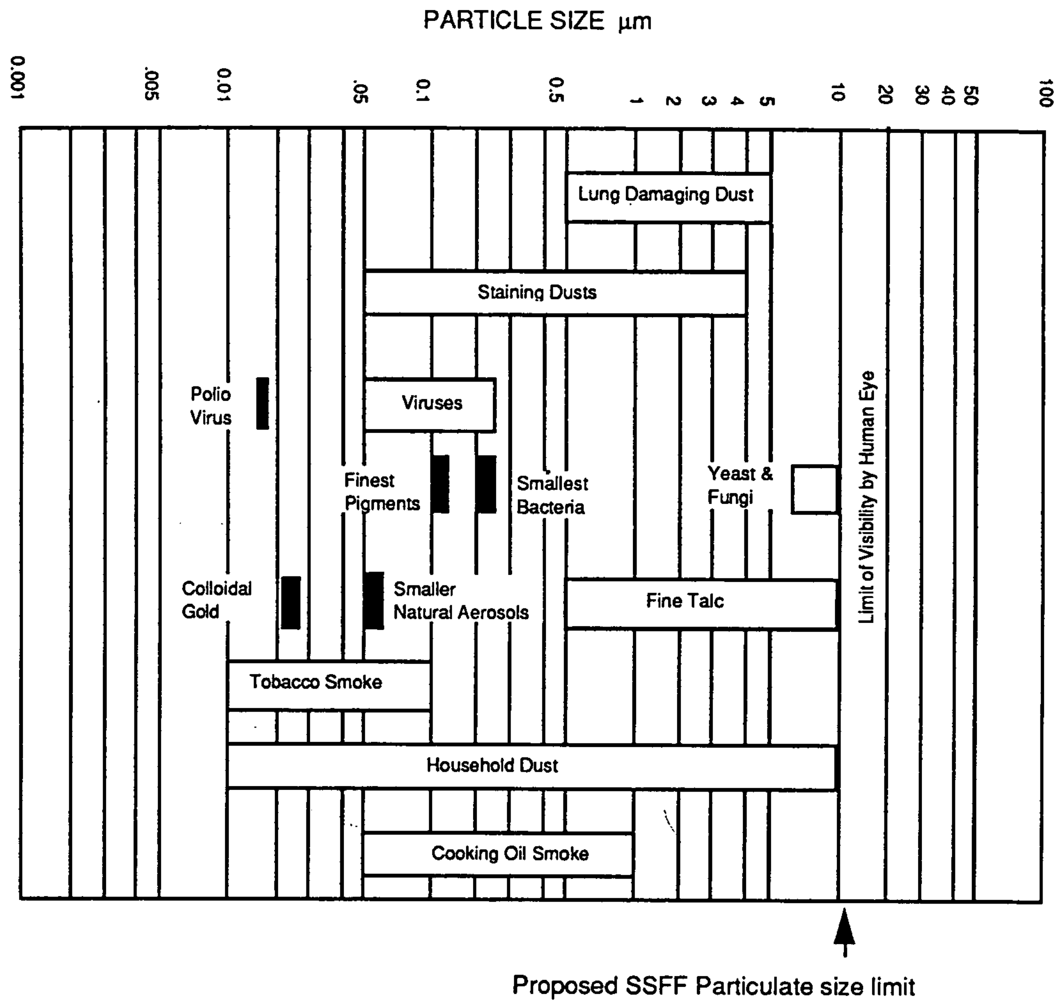

Chart Adapted from *Filters and Filtration Handbook*, R.H. Warring, 1981

Figure 5-1 Impurities in Air

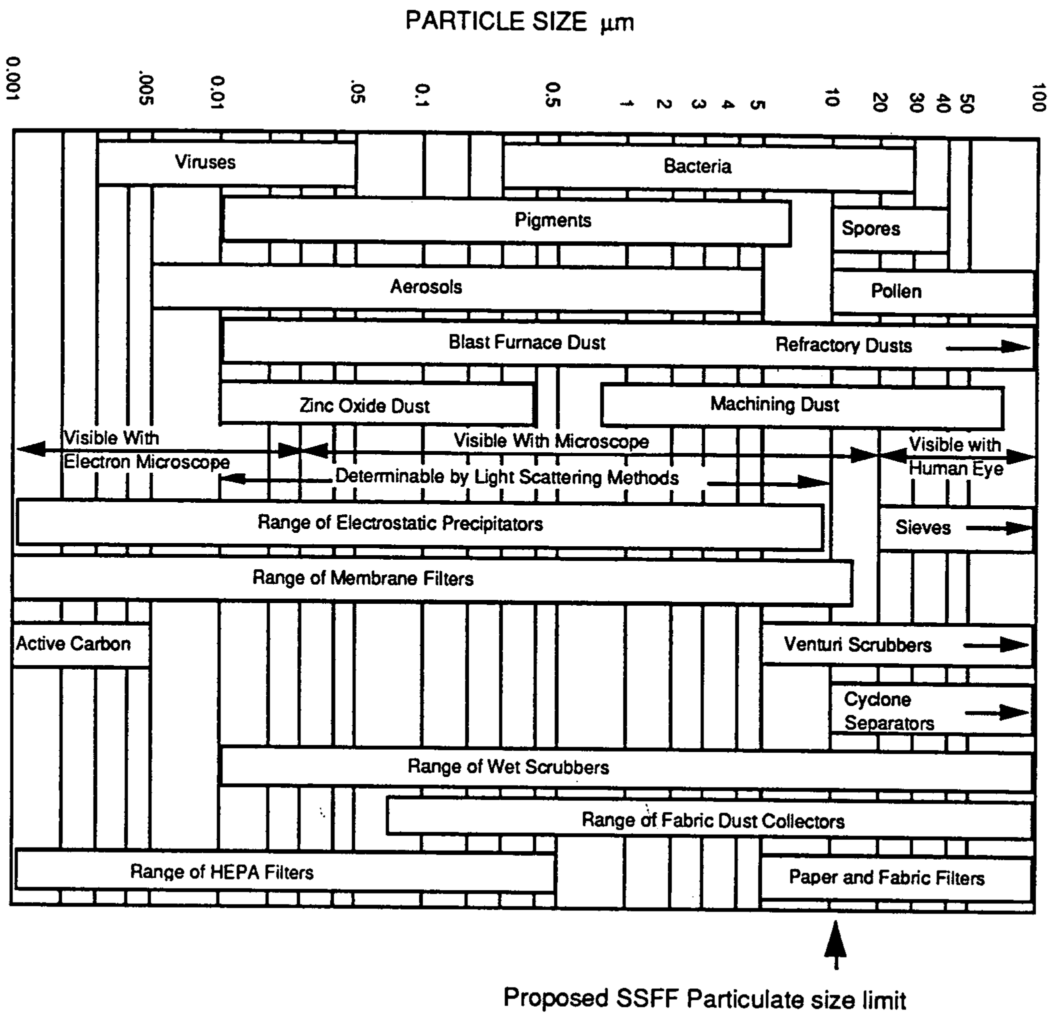

Chart Adapted from *Filters and Filtration Handbook*, R.H. Warring, 1981

Figure 5-2 Contaminant Sizes, Visibility and Separation

5.1.4. Experiences from other Material Processing Experiments

Appendix D provides information collected from previous shuttle-borne material processing experiments. There are also some summary tables from previous safety reviews of other flight type furnaces, including some Soviet Mir furnaces.

In general a minimum of three levels of containment are used in material processing experiments to provide the experiments with two fault tolerance. The Sample/Ampoule Cartridge Assembly (SACA) forms one level of containment. A second level of containment is generally supplied by the experiment container (EAC) itself, which is typically designed as a pressure vessel. A third level of containment can be the use of negative pressure in the experiment chamber. The negative pressure prevents any material from leaking into the cabin environment should the EAC integrity be breached.

The design and operation of SSFF payloads will differ from existing Middeck and Spacelab payloads for the following reasons:[1]

1. On-orbit installation and check-out required for SSFF payloads
2. 90-day operation cycles requiring crew intervention for sample loading/removal and routine maintenance
3. Possible on-orbit sample characterization
4. On-orbit SSFF payload waste processing and/or storage required
5. Venting on SSF is more restrictive than previous shuttle requirements.

These differences will drive the design of the SSFF vent system, as discussed in section 5.4.

5.1.5 Off-Nominal Furnace Operations

Over the 30 year design lifetime of the SSF, the probability exists that there will be a SACA failure which will allow the sample material to enter the secondary containment of a SSFF experiment. Since the sample materials for many experiments are toxic materials, this could become a significant safety issue. Besides the toxic sample materials (arsenic, cadmium, mercury and other heavy metals), there is also the possibility of toxic compounds being formed from combinations of non-toxic materials, given the high furnace temperatures typically used. For example, chloro-fluorocarbons (Freons), although generally considered inert and non-toxic, can dissociate into phosgene and other corrosive gases at elevated temperatures.

Appendix C contains an informal assessment of the consequences of a SACA leak, based on an evaluation of the CGF furnace and the samples scheduled to fly on the USML-1 mission. Essentially, the possibility of a SACA rupturing during processing can never be ruled out. The specific consequence of a rupture depends on a multitude of variables and can only be determined by actual zero-g testing of broken SACA's. The leak flow rates and dispersion patterns will be significantly influenced by the lack of gravity and the specific sample material combinations and material properties.

To provide for safe operation, the SSFF design must prevent a SACA leak from reaching the crew or from leading to a failure of any critical SSF subsystems. In general, the three levels of containment will prevent the crew from being exposed to SACA materials and that concern will not be addressed further. The potential for a SACA leak to contaminate the SSF vacuum vent system and lead to a system failure should not, however, be ignored.

Coupled with the problem of what to do with a contaminated furnace is the problem of detecting when a contamination event has occurred. There is no dependable means at hand to determine if or when a SACA has ruptured. For safety reasons, once a furnace has begun processing, the assumption has to be made that the furnace might have been contaminated with sample material. Before the furnace container is exposed to the crew cabin, the SSFF will have to provide a means to verify that the furnace atmosphere is non-toxic. There are several options to minimize the inherent safety problems associated with sample change outs. These include:

1. Gas purges of the furnace container
2. Visible inspection of the furnace container interior (through a viewport).
3. Using flexible portable gloveboxes for the actual material handling and exchanges.
4. Testing the Furnace Atmosphere for contaminants before opening the container.

The implications of this philosophy are that the SSF vent system may handle single-event vent streams which exceed the nominal limits for contaminants. Options which could avoid this possibility are:

1. Requiring the SSFF to compress and store waste gas
2. Requiring each SSFF payload to incorporate containment failure sensors.

Neither of these approaches appears viable. A waste gas management facility to store all gas generated between resupply missions would probably exceed the total SSFF budget for mass, power, and volume. Qualifying leak detection systems for all possible science samples is felt to exceed the state of the art.

5.2. SSFF Vent System Design Options

A. Design Descriptions

Based on the SSFF vent design requirements, the following venting concepts were developed. Six separate design concepts have been considered to handle the expected wastes produced by the SSFF. A brief summary of each option is provided along with a schematic diagram in Figure 5-3.

1. Direct Venting to Space Station Freedom Vacuum Vent (VS1). The SSFF could vent all waste products directly into the SSF vent system. A particulate filter could be used but no special filtering or processing would be done.

2. Direct Venting Through a SSFF Filter System. The SSFF could vent all waste products directly into the SSF vent system but only after significant filtering and processing. This proposed SSFF Filter system would likely involve a multiple stages of various components with different design functions. For example;

   Stage 1 could be a particulate filter to prevent furnace materials and dust from passing into the SSF vacuum vent system.

   Stage 2 could be a cold trap which would prevent metal and other low vapor pressure substances from further progress into the venting system.

   Stage 3 could be an adsorption system using granular activated charcoal. This would provide a wide-spectrum adsorption capability to minimize the passage of normal furnace out-gassing materials such as cleaning solvents and lubricants.

   Stage 4 could be a special application filter stage designed to absorb or neutralize known hazardous materials in the samples being processed. This stage might have several different internal designs using different active agents but all using the same SSFF interface attachments. Mission specialists might install specific filter components depending on the samples being processed by the SSFF. For example, a special mercury adsorption compound could be installed before the processing of HgCdTe samples. The next PI might have a GaAs sample which would require the astronauts to change out the activated filter for an arsenic neutralizing compound.

The various stages of the SSFF Filter System do not have to coexist within the SSFF rack. It makes more sense for stages 1, 2 and possibility 4 to be mounted directly on the individual SSFF furnace experiment containers. The cold trap could use a branch of the furnace water cooling water for its active temperature control. The particulate filter could be installed at the vent port of the furnace container, where the crew could inspect and change it easily. The special absorption filter might be installed either at the furnace or within the SSFF. Mounting pre-filters at the furnace rack could minimize contamination of the interrack vent lines. Since stage 3 is a general generic all purpose filter it could be installed within the SSFF rack. All of these gas treatment devices would require occasional change-out by the crew.

3. All Vent Wastes are Filtered and Temporarily Stored. A modification to option 2 is to add a small holding tank for waste products. This holding tank would allow accumulating small amount of waste gases which could be produced from long duration sample processing. This holding tank would allow timelining the SSFF venting to minimize any impacts on internal or external SSF operations. The small storage tank would also

allow continuous furnace pressure control without the need for dedicated vacuum vent access.

4. Monitor Vent Wastes and Store Unacceptable Products. Another design option is to continuously monitor the furnace gases by using a SSFF Gas Testing Assembly. This assembly would likely consist of a mass spectrometer along with a molecular turbopump. The turbopump would provide the required vacuum levels to operate a mass spectrometer. If the furnace gases exceed the vacuum vent contamination levels, then the furnace waste gases could be compressed and stored in a high pressure tank. For normal operation, the furnace waste gases would be vented directly to the SSF vacuum vent system. This design option is the current SSFF vacuum vent conceptual design as presented at the CoDR and Quarterly Reviews.

5. Filter All Waste Gases and Provide Continuous Gas Monitoring. The fifth design concept is a hybrid of options 2 and 4. This design monitors the furnace waste products and limits furnace processing when the vacuum vent contamination limits are exceeded. This design incorporates the proposed SSFF Filter System upstream of the Gas Testing Apparatus. This arrangement filters the vent gases before they reach the Gas Testing Apparatus and prevent the mass spectrometer and turbopump from becoming contaminated. The extra filtering will also provide a cleaner operating environment and extend the lifetime of both of these complex and expensive items.

6. Direct Storage of All Vent Products. The SSFF could vent all waste products into a gas storage system. This design option is similar to the SSF Waste Gas Management system in the pre-restructuring configuration. This design concept would require either very large storage tanks or the use of small tanks with high pressure gas compressors. The large storage tank would be a significant volume impact to SSFF, and the gas compressors would require a much more complex venting design and additional power.

5.3. Results and Conclusions

To determine the best overall design option the different concepts were qualitatively compared. Also the design maturity of the individual components was investigated. Lastly, operational safety concerns were addressed for each design concept. The following section summarizes the results.

5.3.1. Design Options Advantages vs Disadvantages

The advantages and disadvantages for the various SSFF vent design concepts were compared. Table 5-3 lists the various qualitative design considerations for each design concept. None of the six proposed filtering systems meet all of the simultaneous design requirements. For example, option 6 is probably the easiest design to integrate because it does not allow any wastes to reach the SSF vent system. However, option 6 is not expected to achieve 10^{-6} torr furnace operating environments. It also places pressure vessels and high pressure plumbing containing potentially toxic materials in the habitable volume, a significant safety issue.

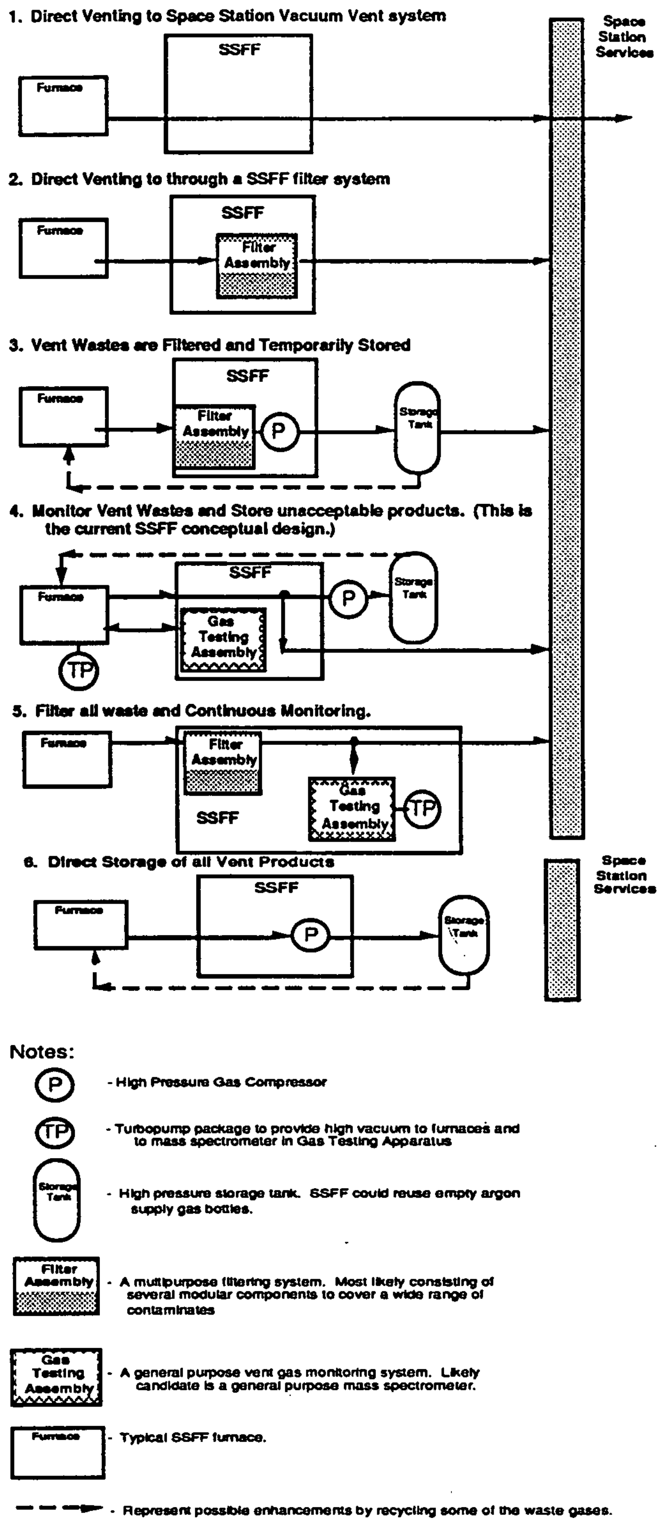

Figure 5-3 Diagram of SSFF Vent System Design Options

Control Method	Advantages	Disadvantages
1. Venting products directly overboard	Low Volume, mass and power requirements. Simple design No vent monitoring required	Contamination of other experiments on vent line and external to Space Station Probably exceed allowable SSF pollution limits Permanent contamination of Space Station vent line . Sample leaks produce severe contamination on-orbit and stops furnace processing. Disruptions to other vent line users during pressure control or during unexpected venting. Does not provide furnace with high vacuum (10^{-5} torr)
2. Filtering vent products and venting overboard	Minimal volume, power requirements Nominal venting operation probably remains below SSF pollution requirements Processing with a sample leak might be possible in some situations.	Some internal and external contamination still occurs. Disruptions to other vent line users during pressure control or during unexpected venting. On-orbit filter change outs required (Possible Crew Safety problems) No gas monitoring to prevent SSF contamination Does not provide furnace with high vacuum (10^{-5} torr)
3. Vent Waste Gases are Filtered and Temporarily Stored	The temporary storage tank improves the ability to timeline gas venting. Pressure control of SSFF furnaces will not depend on other experiments connected to vacuum system Nominal venting operation probably remains below SSF pollution requirements If there is a sample leakage, some material processing can still be done by changing out waste gas tanks. The waste gas storage tank allows re-using waste some waste gases, reducing gas supply requirements.	The use of a gas compressor significantly increase the power and volume requirements for SSFF. There are significant safety issues with mixing various contaminates in the same storage tank. Does not provide furnace with high vacuum (10^{-5} torr)
4. Monitor Vent Wastes and Store Unacceptable Products. This is the current SSFF conceptual design	The Gas Monitoring System provides confirmation that the vent system is not being contaminanted. Some waste gas recycling is possible. If there is a sample leakage, some material processing can still be done by changing out waste gas tanks. Turbopump provides high vacuum to furnace processing.	This arrangement exposes the Mass Spectrometer and Turbopump to furnace and sample contaminants. This will contaminate both items and make them inoperable. High power requirements to run the gas compressor for waste gas storage and the turbopump/mass spectrometer for gas monitoring. Waste gas storage bottles require additional storage volume. There are significant safety issues with mixing various contaminates in the same storage tank. High pressure tanks are zero fault tolerant for toxic material (pressure vessel protection only).

5. Filter All Waste Gasses and Provide Continuous Vent Monitoring	The filter system protects the Gas Testing Apparatus and Turbopump. No power required for gas compressor. No volume impacts from storage bottles. Turbopump provides high vacuum to furnace processing.	Disruptions to other vent line users during pressure control or during unexpected venting. No processing allowed after sample leakage. No possibility to recycle waste gasses.
6. Direct Storage of All SSFF Vent Products	No contamination impacts on other Space Station users Sample/Ampoule/Cartridge failures have not impact on venting operations.	Large volume/power required for small or large tank sizes Small storage tanks require gas compressors Large storage tanks require significant volumes High pressure tanks are zero fault tolerant for toxic material (pressure vessel protection only). Low Pressure tanks are one fault tolerant. (neg pressure and pressure vessel protection) There are significant safety issues with mixing various contaminates in the same storage tank. Does not provide furnace with high vacuum (10^{-5} torr)

Table 5-3. Design Options Advantages and Disadvantages

5.3.2. SSFF Venting Component Summary

The following section summarizes the level of maturity for the components described in the SSFF design concepts.

1. Storage Tanks

High pressure storage tanks are a common feature for several of the SSFF vent design concepts. A high pressure tank in use today which could easily fill this design requirement is the nitrogen gas storage bottle designed for the Manned Maneuvering Unit. The vendor sheets for this tank are provided in Appendix E. These nitrogen tanks have the following design characteristics:

Service Pressure	3000 psi
Mass	28.5 lbs
Size	10.1 in diameter x 31.3 in long
Volume	1631 cu in pressurized volume (0.94 cu ft)
Material	Kevlar-49 aramid fiber and epoxy resin wound on aluminum liner.

This type of tank is also flying on Spacelab missions such as USML-1. The USML-1 CGF furnace uses one of these tanks to store its argon gas supply.

There are some safety concerns with using high pressure storage tanks for general purpose waste disposal. There are few controls to prevent the mixing of incompatible materials at high pressure. Also, compatibility of the pressure vessel liner with vent gas components must be considered. Based on the previous Spacelab experience, the maturity of this design component must be considered high.

2. Gas Compressor

No gas compressor has been found to match the design requirements for SSFF. The vendor sheet for a vacuum pump which also works as a gas compressor is included in Appendix E. The maximum output pressure for this pump is 90 psia. The design of a low vibration flight-qualified compressor capable of 3000 psi appears to be a significant engineering development. The size, power and mass requirements for a compressor meeting the likely performance requirements could easily outstrip the available SSFF resources.

3. Mass Spectrometer

Several SSF users have identified a requirement for of a mass spectrometer. Appendix E provides vendor sheets proposing a mass spectrometer for the SSF Residual Gas Analyzer. This unit meets most of the SSFF design requirements and is based on the flight proven Induced Environmental Contaminant Monitor (IECM) which has flown on several space shuttle missions.

4. Turbomolecular Pump

Appendix E also contains the vendor sheets for a turbomolecular pump which was selected for the pre-restructuring SSF Waste Gas Management System. This pump's specifications appear to meet the design requirements for SSFF use. No such pump has been flight qualified.

5. Filter System

Providing filtering systems for space flight is not a new technology. Reference 4 summarizes the major experiences for the past 15 years. The following is an excerpt from that report.

1. Space Shuttle

The Space Shuttle Environmental Control and Life Support Systems (ECLSS) has several subsystems performing specific tasks. The Air Revitalization System (ARS) removes heat, moisture, odor, CO_2, skin and hair, etc. from the circulating air. Redundant cabin fans propel air to two canisters in parallel containing activated charcoal mixed with LiOH. A restricting orifice in the ducting forces 120 lb/hr of air through each canister. Since components on the orbiter are space qualified (i.e. low offgassing), the limiting factor on each canister is the CO_2 removal capacity; each canister lasts approximately 12 hours.

2. Spacelab

The Environmental Control and Life Support (ECLS) subsystem on Spacelab consists of the Atmosphere Control Section and the Atmosphere Revitalization Section. Within the Atmosphere Revitalization Section (ARS) are two LiOH cartridges for CO_2 removal and odor control which are identical to those used on the Orbiter. In addition, a trace contaminant scrubber is installed in the tunnel airduct for the removal of carbon monoxide and a wide range of trace contaminants. Since this canister is intended to provide payload developers with additional flexibility by allowing use of "off-the-shelf" commercial components, it is similar to the Gaseous Contaminant (GCRU) of the Material Science Glovebox (MSG).

The canister consists of a sequentially packed bed approximately 9 inches ID, 16.5 in. long containing 5.25 lbs. of activated charcoal, followed by 3.0 lbs of phosphoric acid treated charcoal, then 0.74 lbs. of 2% platinum catalyst deposited on charcoal. With the design flow rate of 4 ft^3/min, most contaminants can be removed by the activated charcoal. Only ammonia, carbon monoxide, and methanol require additional provisions. The acid-treated charcoal controls NH_3, while the platinum catalyst converts the CO to CO_2. Methanol is partly removed by the charcoal and partly in the condensing heat exchanger. The

canister is designed for 7 days use, after which is must be replaced.

3. Space Station Freedom

The Environmental Control and Life Support System (ECLSS) for Space Station Freedom contains a Trace Contaminant Control Subsystem (TCCS) which removes volatile gaseous contaminants. The mission of the SSF, permanent on-orbit presence, is in a marked contrast with the short duration (<10 days) for the Orbiter or Spacelab. Consequently different configurations for trace contaminant removal equipment are utilized. In particular, on-orbit replacement of expendable canisters is minimized by separating the CO_2 removal function from trace contaminate removal. In addition, space constraints preclude massive beds of adsorbent materials. Consequently, the primary absorbent (charcoal) is segregated into two beds: the first for well absorbed materials, the second for poorly absorbed chemicals.

The first absorber is a non-regenerable bed designed for long-term (45-90 day) capacity for the anticipated easily- absorbed materials. The second bed is regenerable and is sized for one day of operation with the least well absorbed material. At the end of each cycle the regenerable bed is isolated from the circulation line, then subjected to simultaneous vacuum and heating to debsorb the chemicals. These chemicals are then passed through a heated catalytic oxidizer. Acid vapors are removed by a LiOH bed before the oxidizer effluent, mainly CO_2 and H_2O), is discharged overboard.

4. Biorack

Biorack is a small Class III biological safety cabinet which was developed by the European Space Agency (ESA) for the Spacelab D-1 mission. It was used exclusively for biological studies and was designed with an integral activated charcoal bed to provide control for volatile chemical contamination, primarily ammonia, isolpropanol, glutyraldehyde, and formaldehyde.

The 1600 gm of NORIT-REF charcoal is contained inside the primary filter assembly, with the entire air flow passing through it. Biorack is the only glovebox which has been flown on Spacelab, and represents the available flight experience with a glovebox-specific contaminant removal system.

5. General Purpose Workstation (GPWS)

The GPWS is a rack-mounted Class II Biohazard Cabinet for use in life science investigations on Spacelab. It uses airflow entrainment to control gaseous, liquid, particulate, and microbiological matter. During normal operation 300 cfm of air is recirculated through the GPWS work space. Since 20 cfm of air flows into the GPWS to form an air curtain in front of the user, an

equivalent amount of air is exhausted to the cabin through the Main TCCS canister. This canister is 14 in. ID and 10 in. long with 1 in. of environmental grade LiOH, then 6 in. of Barneby-Cheney BD charcoal, and 3 in. of Barbeby-Cheney CI charcoal. An additional Vent TCCS canister is also included which has an ID of 1.9 in. with the same length and bed depths of charcoal.

Existing space-based technologies for control of trace gaseous contaminants utilize two primary materials: activated charcoal and lithium hydroxide. The latter is used primarily for inorganic removal (excluding NH3), while charcoal is used for most organic materials.

Several materials are not well removed by either of these chemicals, most notably low molecular weight alcohols, carbon monoxide, and ammonia. The last chemical can be controlled by charcoal treated with dilute phosphoric acid, while a platinum catalyst deposited on charcoal will oxidize the CO at room temperature. Low molecular weight alcohols show increasing affinity for water with decreasing molecular weight and appreciable amounts can be removed in condensing heat exchangers. The adsorber canisters alone cannot remove methanol on either the Shuttle or Spacelab, and the condensing heat exchangers are necessary to maintain control of these materials.

This history of spacecraft filtering shows that using multiple stage filters has been standard design practice. A passive absorber based on activated charcoal for organic removal and lithium hydroxide for inorganics is also proposed for the SSFF filtering system. Figure 5-4 shows the filters used on Spacelab. A similar design should be considered for the SSFF system.

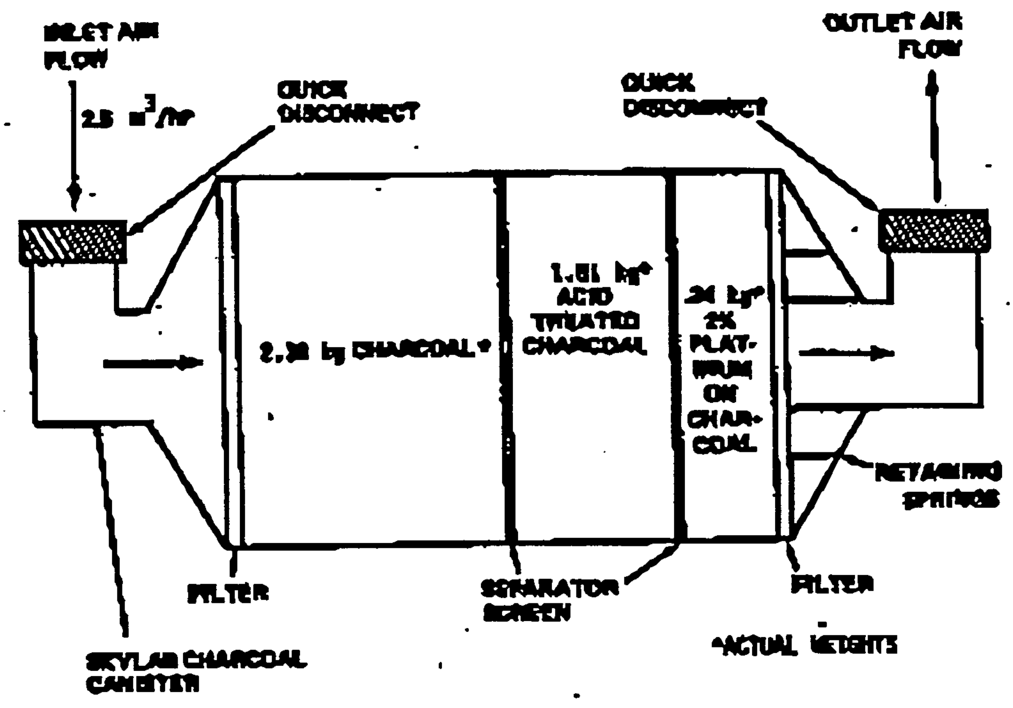

Figure 5-4. Spacelab Trace Contaminate Removal Cannister

5.3.3. Safety Considerations

Based on the significant safety concerns when using toxic materials for on-orbit material processing there is no design which is totally safe. The best design option is to totally prevent the release of furnace toxic materials and this is best done with option 6 where all vent products are stored. However, this option places significant resource requirements on the SSFF with respect to mass, volume and power. Research has failed to find a flight-rated gas compressor which meets the SSFF requirements. In addition, the vibration levels created by operating a high pressure compressor within the SSFF rack are expected to be intolerable to sensitive payloads.

The next best design option in regards to safety is option 5. This option filters all vent products from the furnace modules and continually monitors the gases vented to the SSF vent system. By monitoring the waste gases, SSFF can provide positive assurances that it is not exceeding the vacuum vent contamination limits. Gas monitoring can provide early warning that SSFF filters need cleaning or replacement.

5.4. SSFF Vent Task Recommendations

5.4.1 Recommended SSF Allowable Vent Contamination Levels

The Space Station Freedom vacuum vent allowable material concentrations table should be modified to allow the venting of reasonable waste products. For example, cabin air which could contain contaminate levels acceptable to long term human exposure should be considered ventable under reasonable guidelines. In addition, some guidelines must be established to address emergency access to the vent line for contingency venting. There should be contingency single-event allowable material concentrations established for the SSF vacuum vent system.

The SSF vacuum vent line should accept the possible vent wastes from an ampoule failure during science processing. SSFF experimenters neither predict nor fully detail the consequences of a broken ampoule. No ampoule failure detection devices have been developed to-date. Even if SSFF were to detect an ampoule failure, there is no way to prevent the toxic sample material from contaminating the furnace container interior.

SSFF recommends that the SSF vacuum vent system be designed to accept the vent wastes from one broken ampoule per 90 day SSF mission. This would amount to receiving about 32 milligrams of material, based on the following analysis:

1. The sample material was mercury (Picked due to its high vapor pressure and density)
2. The furnace container is the size of the CGF Experiment Apparatus Container (EAC). (The CGF EAC is about 15 cu ft compared to the total available rack volume of about 40 cu. ft.).
3. The average gas temperature within the EAC is 50°C. (Based on maximum touch temperature requirement of 45°C. Actual CGF operating temperatures are below 30°C)
4. The EAC atmosphere is fully saturated with the sample material.

5.4.2. Recommended SSFF Vent Design Concept.

This report recommends Design Option 5, Filter all Waste Gases and Provide Continuous Gas Monitoring as the SSFF venting design concept. This design option provides the safest on-orbit furnace operation with the most reasonable use of SSFF resources. The major components of this design are all available without significant development costs. There are several other SSF experiments and monitoring equipment planning on using a mass spectrometer. A turbomolecular type pump package had already been selected for the pre-restructuring SSF Waste Gas Management System, before that task was cancelled. A similar system will work for the SSFF, since the design requirements are nearly identical. If the furnace vacuum requirements were reduced, the mass spectrometer could operate with a much smaller high vacuum pump, such as an ion pump device.

The sample-specific filters will require additional development once specific principal investigators are selected. However, this concept is already used by many investigators in their ground-based furnaces and can be easily adapted to flight use. The particulate filters and generic charcoal filters use current technology. Spacelab already has a Trace Contaminant Control system which uses specially prepared charcoal.

5.4.3. Design Requirements for the SSFF Filtering System

The following design requirements would apply to the proposed SSFF Filter System Design

Maximum flow rate	120 liter/min
Maximum ΔP at design flow rate	2 psid
Maximum size	5000 in^3 (This volume limit may be spread between the several component locations)
Maximum mass	80 kg
Filterable Particulate Size	0.5 µm at 99% efficiency

Gas concentrations leaving the filter should be below maximum SMAC levels.

Filter change out time should be kept to a minimum.

Reusable filters which could be recharged on-orbit should be considered due to the resupply restrictions.

Expected compounds to filter:

1. During normal operation very little filtering will be needed, except for carbon monoxide.

2. Sample-specific filters based on experiments being processed.

References

1. Proceedings of a Safety Assessment of the MSAD Science Facilities for Space Station Freedom, December 5, 1990. Sponsored by NASA Office of Space Science and Applications Microgravity Science and Applications Division, Contract Number NAS1-18228, Task Assignment Number 9

2. Workshop Proceedings for Space Station Freedom Toxic and Reactive Materials Handling, November 29 - December 1, 1988, TBD

3. Boeing Envelope Drawing for Laboratory Vacuum Subsystem, Dwg No. 683-18005, revision unknown,

4. U. S. Laboratory Materials Science Glovebox Preliminary Gaseous Contaminant Removal Unit Assessment, Contract Number GY 5506, TBE document number SS88-SE-0256, July 1990.

5. Space Station Freedom Hazardous Contamination Study, Draft Copy, JSC Operations Integration Office, March 1990.

6. Space Station Furnace Facility (SSFF) Capability Requirement Document, March 8, 1990.

7. Spacelab Payload Accommodation Handbook, SLP/2104, revision 1, Nov 1985.s

8. WP01 Vacuum System CEI Specification

9. Review Board Report for the Space Station Furnace Facility Conceptual Design Review.

10. *Airborne Particulate Matter and Spacecraft Internal Environments*, Benjamin Y. H. Liu, Kenneth L. Rubox, Peter H. McMurry, Thomas J. Kotz, Dane Russo, SAE paper 911476, 21st International Conference on Environmental Systems, July 15-18, 1991.

320RPT0009

SPACE STATION FURNACE FACILITY (SSFF)

STUDY REPORT ON ORBITAL REPLACEMENT UNITS (ORU's)

DR - 2

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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320RPT0009

SPACE STATION FURNACE FACILITY (SSFF) STUDY REPORT ON ORBITAL REPLACEMENT UNITS (ORU's)

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
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REFERENCE DOCUMENTS

The following reference documents and data items, as available at the time of preparation, were used as sources of Space Station system definition data and ORU related requirements in this study report. Definition of the SSFF subsystem hardware design configurations used in defining the ORU's is detailed within the body of this report.

Ref.	Document Number	Title
1	SS-SRD-0001, Sec 3 Level III Systems	System Requirements, Space Station Freedom Program Requirement Document
2	SS-HDBK-0001, Vol 1	WP01 Elements Payload Accommodation Handbook, United States Laboratory Module
3	NASA-STD-3000	Space Station Man-Systems Integration Volume IV, Standards
4	NHB 5300.4 (1E)	Maintainability Program Requirements for Space Systems
5	D683-10124-1	Maintainability Design Criteria
6	D683-10518	Logistics Analyses: Functional Flow,Volume 6, Analysis, Maintenance Functional Maps, Laboratory Element
7	D683-10318	Resupply/Return Analysis, ORU, Volumes 1 & 2 Candidate List
8	JA55-032	Space Station Furnace Facility Capability Requirements Document
9	320RPT0008	Subsystems Concept Report
10	SSFF-MI-001	Module 1, Study Report
11	MIL-HDBK-217E	Reliability Prediction Of Electronic Equipment
12	NPRD-91	Nonelectronic Parts Reliability Data
13	320RPT0011	SSFF Mission Operations Report

ABBREVIATIONS AND ACRONYMS

AA	Avionics Air
CCU	Core Control Unit
CD/ROM	Compact Disk/Read Only Memory
CGF	Crystal Growth Facility
cm	Centimeters
CMCU	Core Monitor and Control Unit
CPC	Core Power Conditioner
CPD	Core Power Distributor
DMS	Data Management System
EPS	Electrical Power Subsystem
ER	Experiment Rack
ESS	Essentials (Power Supply)
FAU	Furnace Acquisition Unit
FCU	Furnace Control Unit
FO	Functional Objective
GDS	Gas Distribution System
HDR	High Density Recorder
ISPR	International Standard Payload Rack
min	Minutes
MR	Mobility Restraint
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
MTC	Man Tended Capability
NASA	National Aeronautics and Space Administration
ORU	Orbital Replacement Unit
PCDS	Power Conditioning and Distribution Subsystem
PMC	Permanently Manned Capability
PMZF	Programmable Multizone Facility
QD	Quick Disconnect
RPCM	Remote Power Control Module
RPDA	Remote Power Distribution Assembly
SRD	Science Requirements Document
SRU	Shop Replaceable Unit
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To Be Determined
TCS	Thermal Control Subsystem
USL	United States Laboratory
VES	Vacuum Exhaust System

1.0 INTRODUCTION

This report is a summary of the ORU assessment study under the Space Station Furnace Facility (SSFF) contract NAS8-38077. It is being prepared at the end of the extended Phase A/B preliminary design efforts so that the benefits from as much of the system definition tasks can be taken as possible. The SSFF system configuration to be discussed in this study is shown pictorially in Figure 1. The facility consists of three contiguous Space Station double rack positions integrated as a core rack and two experiment module racks. The core support rack contains the majority of the common subsystem support equipment which interfaces between the station and the interchangeable experiment modules. These subsystems include power distribution, data management, video processing, thermal control, and gas distribution. As explained in the subsystem concept reports, Ref 9, it is necessary to locate portions of the subsystem equipment in the experiment racks along with the furnace enclosures to provide for complete system control and safety. An interconnect cable tray, Figure 2, is also required as part of the system to connect the various service feeds between the core and the experiment modules. These feeds are integrated into a tray to simplify the on orbit assembly of the facility. As a result, the core rack and experiment racks must incorporates features (different from the standard space station racks) which permit their use with the interconnect tray assembly. These features result in SSFF specific racks, which are described in detail in the Mechanical Structures Subsystem section of Reference 9. Though shown in a left hand position in all the figures in this report, the core rack can be located in almost any position relative to the adjacent two experiment modules by the rework of the cable tray; i.e., the core rack could be located on either the left, the right, or in the middle of the two experiment modules.

2.0 SCOPE

This study includes the definition of ORU's in the SSFF provided core subsystems and in the distributed components required in the experiment modules (furnace racks). It is based on the subsystem descriptions and the component definitions provided in Reference 9, and the system packaging concept described herein. The selection of ORU/SRU's has largely been made on a subjective basis using the groundrules given in Section 3.0. Some detail MTBF data has also been collected and was used to identify the logistic planning and the on orbit storage data given in Section 5.0.

In addition to the SSFF ORU's, a candidate list of ORU's has been identified (from Reference 10) for the Experiment Rack, Furnace Module 1. The requirements for Module 1 were extrapolated from the Crystal Growth Facility (CGF) data base, which is anticipated to be the first of several possible flight furnace configurations. The SSFF strawman subsystem design also included the PMZF furnace as a candidate for Module 2; however, at this time there is not sufficient data on the PMZF (or the other possible furnace candidates) to produce any substantial data changes to the ORU list identified for Module 1, reference Section 4.3.

To limit and bound the scope of this study a set of ground rules and assumptions have been established in Section 3.0 which attempt to define the on orbit storage and maintenance requirements, and the resupply/ logistic philosophy which play a major part in the specific selection of hardware to be ORU's or SRU's. For the sake of simplicity, it has been assumed that (within reason) there are no specific restraints on: 1.) the available storage volume (up to one half a double rack), 2.) the manifesting of replacement or change out units, or 3.) the cost for deliver to orbit. Only a limit on available astronaut time for effecting repairs has been acknowledged as a constraint in the MTC time frame. Another key study factor, which is tied closely to this same philosophy base, is the operational availability goal of the SSFF (as yet undefined by the program). This report assumes that even with the semi-unlimited resources described, a nominal 130 day down time could be experienced by the facility in the event of an unplanned failure. This down time would be even longer if logistic stocking limitations exist. For example, the types of unlimited resource factors in the ORU assessment, which have not been looked at in detail, are the quantity and cost of spare equipment which must be kept in a flight ready status on the ground in order to insure this 130 day availability. A branch of that assessment would be the level of vendor stocking of spare parts so that the lead time for repairs or refurbishment on hardware returned to the ground could be minimized. All of these factors would require further evaluation in order to complete a full logistic analysis of the SSFF; however such an effort is outside the scope of this study and the current contract. These details should be high priority design and cost trade studies for the phase C/D effort.

3.0 DEFINITIONS, GROUNDRULES AND ASSUMPTIONS

This report has established the following definitions, groundrules, and assumptions governing the SSFF subsystem ORU selections.

3.1 DEFINITIONS

- Orbital Replacement Unit (ORU)

  The designated level of component or subsystem hardware that can be removed and replaced on location under orbital conditions. This does not preclude removal and replacement of ORU's during ground processing.

- Shop Replaceable Unit (SRU

  Any item/subassembly of an ORU whose replacement constitutes the optimum intermediate or depot level of repair action for a higher indenture item. Normally associated with items removed from ORU's in intermediate and depot shops. (Items removed and replaced during repair of ORU's at the maintenance workstation are SRU's.)

  Work Package 1 has requested the following additional definition be added for certain replacement hardware.

- Orbital Exchangeable Item (OEI)

  The lowest level of component or subsystem hardware that is designed to be replaced on orbit, but the low frequency of change out or the inherent characteristics of the hardware do not warrant ORU status. Examples of hardware elements that may fall into this category are wire bundles, standoff header pipe sections, and passive assemblies.

  OEI's have a MTBF > 10 years and therefore the accessibility requirements for ORU's is not warranted. (Hardware assemblies which require rapid change out due to functional criticality or safety hazards can not be OEI's).

  This classification provides a means to identify removable items which do not have to satisfy the other ORU maintenance/logistical requirements.

- Design (Useful) Life

  The total useful (active) life span of the SSFF (Core rack and its distributed support systems) before it is considered unacceptable for further use. This span is extended for component level elements by the proper performance of preventative and corrective maintenance.

- Operating Life

  Operating life is the specified operation time (or number of operating cycles) that a component/subsystem can accrue before replacement or refurbishment without risk of degradation of performance beyond acceptable limits.

- Mean Time To Repair (MTTR)

  The estimated time to repair a defective component or subassembly based on the complete replacement of the unit (ORU) or of a constituent (SRU). To be completely meaningful the MTTR must also be correlated to elapsed time and number of men involved.

- Mean Time Between Failure (MTBF)

  A statistically established time interval corresponding to the mean life of a component from the date of its entering a continuous service cycle to the point of its failure to function to specification.

3.2 GROUNDRULES

The design life of the SSFF is 30 years (same as the Space Station itself); however, the selection and procurement of components for the subsystem hardware elements will not be constrained to 30 year qualification requirements if cost is substantially greater than a Shuttle/Spacelab qualified equivalent.

As a result of waiving the thirty year operational life of individual components, the SSFF will be assigned an initial operational life (before major overhaul) of ten (10) years for the purposes of this study. This will apply primarily to the core rack, since the experiment modules are also assumed to have a four (4) year change out cycle and would be available for refurbishment at least twice before the ten year term.

ORU's are identified primarily at the box/component level. Only those board level replacements and on orbit repairs/preventative maintenance tasks which can be accomplished and verified in less than eight (8) hours will be identified as on orbit SRU's/tasks during MTC. With a relaxation of this maintenance time restriction a reduction in ORU resupply weight and volume might be made in PMC.

Furnace repair and reconfiguration (on orbit) is not included in this study since that concept is an extensive study unto itself (see Reference 10), however, the ORU (maintenance) portion of the Module 1 study is summarized herein.

On orbit repair of the thermal control system (water filled) components is ruled out due to the inability to easily drain and refill the system. TCS ORU's will be packaged in modular subassemblies with QD's for easy removal and replacement.

All ORU's with a predicted MTBF in a given 90 day period will be manifested for delivery 180 days prior to that time and stored on orbit. During the MTC visit these items will be change out the 90 day time frame immediately before service expiration.

ORU design must satisfy the accessibility, maintainability, and human factors requirements in D683-10124-1.

In dealing with incipient hardware failures as a main consideration in the ORU definition, this report does not, however, include any Hazard Analyses considerations or Failure Modes and Effects Analyses (FMEA) factors which might result in other induced hardware failures and/or the propagation of failures into other system elements.

3.3 ASSUMPTIONS

On orbit storage of the SSFF operational support equipment (samples, glovebox, tools, replacement tape recorder, etc.) and designated ORU's is assumed to be in a storage rack separate from the three double rack facility.

Those components which have a MTBF of less than 10 years will be assumed automatically to be stocked in a direct replacement ORU. Those above the ten year MBTR will be assumed to be replaced or refurbished to original condition by a planned ten year major overhaul. The exact timing of this overhaul would be established by the Phase C/D contract.

Furnace Modules will be assumed to have a target operating life of four years in this study. Those SSFF support system components in the furnace racks which have MTBF's less than four years would be considered as stocked ORU's.

ORU/component failures in either furnace rack are assumed by design to have no impact on the continued operation of the other rack. Repairs can likewise be accomplished without removing the core and other rack from service. The core service lines to the rack in question may have to be disconnected for safety reasons to make the needed repairs. No repairs will be made with power or pressure on the affected system.

It is assumed that the SSFF subsystems have sufficient instrumentation and monitoring means to permit most non-critical ORU failures (except for some leaks) to be confirmed from the ground. This means that no additional troubleshooting service time is necessary before repairs begin.

For certain non-critical ORU failures, work arounds for continued operation in a degraded manner would be real time decisions. Critical ORU failure will result in an automatic on board system shut down.

Major accidents/failures such as a fire, coolant hose or ampoule rupture are assumed to require the entire system affected (IFEA, rack) to be returned to the ground for refurbishment.

4.0 SSFF ORU STUDY ANALYSIS

The SSFF ORU's identified in this study come from three basic hardware assemblies: the core rack systems, the SSFF provided support systems in the experiment modules, and those elements in the furnace module itself which have a MBTF less than the program target. The schematics for the SSFF subsystems in both the core and experiment modules are shown in Figures 3 - Figure 6. Detail information on the components being considered as candidates for the individual hardware elements on these schematics are documented in Reference 9. A cursory analysis of the MTBF was made of these hardware items to bracket the probable service life of most ORU components and subassemblies. Since several of the hardware items selected for use in the SSFF subsystems are currently under development for SSF and have no life data available yet, the analysis is largely based on engineering judgement from industrial data for similar components.

4.1 CORE SUBSYSTEM ORU'S

The integrated packaging design of the SSFF core rack has been developed in three dimensions in a CAD model as shown in Figure 7 - Figure 10. A simplified mock up of this rack arrangement has also been built in support of this study and the contract effort.

As shown in the integrated rack figures, the various subsystem components were grouped as much as possible into unique modular units which are tray mounted on heavy duty slide assemblies for relatively easy installation and removal. The modules have been identified on the figures and are grouped by subsystem in Figure 10 - Figure 13 . The following sections will explore each of these subsystems in detail and will give design specifics on the arrangement of hardware items for reference later in Section 6.0 where the ORU replacement operations are described.

4.1.1 THERMAL CONTROL SUBSYSTEM

As was stated in the groundrules, the TCS system cannot be opened on orbit for the replacement or repair of an individual element due to the loss of coolant; therefore, the complete TCS modules and any isolated components (such as the heat exchanger and individual hoses) are automatically candidate ORU's. Each TCS element consequently will have QD's at each end to enable its removal and replacement without the release of coolant. Should the need for an ORU replacement be a leak, the level sensors provided on the system accumulators is currently the only means by which a leak can be detected remotely. Such an indication would not become evident, however, until a considerable volume of liquid had already escaped. At one time the SSF had a requirement that leak detectors be installed at every fluid joint. Since satisfying this requirement would be very complicated and expensive it was dropped from the program. It is recommended,

however, that the Phase C/D contain a task to study the feasibility of a simple system for "area" sensing and permit early detection of minor leaks. Once detected the component/subassembly involved would be immediately isolated from system pressure if possible. When an astronaut is available the leaking element would be disconnected and sealed by the mating cap (if a QD) and/or by a bag.

The TCS ORU's in the core rack are listed in Table 1 and shown in Figure 14 - Figure 19 along with key technical parameters for each item identified.

TABLE 1. SSFF THERMAL CONTROL SYSTEM ORBITAL REPLACEMENT UNITS (ORU'S)

ORU[2]	QTY	FIGURE
Heat Exchanger	1	14
Pump Module Assembly	1	15
Coolant Control Valve Assy	1	16
Coolant Rtn Valve Assy	1	17
Cold Plates		18
6.50 x 11.80	2	
16.00 x 28.00	6	
13.25 x 28.00	2	
Hose Assembly[1]		19
Sta. Supply	1	
Sta. Return	1	
Rack Rtn	1	
Cold Plate Connect	7	

1 The remaining TCS interconnect hoses are an integral part of the various module/cold plate ORU's and only the ten (10) noted are separate ORU's (QD's on both ends).

2 A primary power and data system harness has pig tail feeds to the TCS components. A major failure in these lines would necessitate a real time "work around" until the major scheduled overhaul. These are not considered practical ORU/SRU items and would therefore fall into WP 1's category of an OEI with ground replacement as the likely mode of repair.

4.1.2 POWER SYSTEM ORU's

The power system in the core rack consists of the components shown in Figure 11 arranged into two separate output banks (one for each experiment rank) with the internal core equipment also distributed equally (for load purposes) between the two banks. Each bank is fed by a separate Station bus. The two station buses are kept isolated even where they are tied together in the essentials power supply to feed the core and furnace rack DMS computers (CCU and FCU). The essentials power supply is intended to allow the SSFF to make a safe shut down if one of the Station buses is lost.

The architecture of the system is based on the use of CGF and PMZF as the strawman furnace designs for Module 1 & 2. These strawmen were expected to be a bounding set for the power requirements in terms of number of circuits and load. Other furnace configurations could be programmed to use the existing control circuits in either bank 1 or 2. A junction box has been provided in both the core and furnace racks to allow grouping of the output circuits for the particular zones and required power levels of the new furnace. The other elements of the power system are also modular allowing for reconfiguration/ rewiring of the basic power circuits (on the ground) for future furnaces which might be outside the CGF/ PMZF bounds.

Because of the complex wiring schemes within most of the power system boxes, the box level has been selected for ORU definition in the core rack. A few individual cards, components, and power system subassemblies within the boxes might be candidates for on orbit replacement; however, this would be highly dependent on the ability to isolate the fault, the astronaut time allotted to payload repair functions, and the confidence factors the crew would have to have before entering into such repair operations. A study of the packaging details would need to be made before any of these sub levels are defined as ORU's. Cable harnesses and the manual circuit breakers on the two station feed lines are the only other ORU's in this system.

The PCDS ORU's in the core rack are listed in Table 2 and shown in Figure 20 - Figure 25 with key technical parameters for each item identified.

TABLE 2. POWER CONDITIONING AND DISTRIBUTION SYSTEM ORBITAL REPLACEMENT UNITS (ORU'S)

ORU	QTY	FIGURE
Manual Circuit Breaker	2	20
RPCM, Type 5	2	21
Primary Distribution Box	1	22
Essentials Power Supply	1	23
Core Power Conditioning Bank	2	24
Core Junction Box	2	25

4.1.3 GAS DISTRIBUTION SYSTEM

The gas distribution system elements found in the core rack are shown in Figure 12. They consist of a gas supply module, which provides the consumable gas utilized by the experiment modules during the processing of specimens, a gas control tray assembly, the contamination monitoring system electronics, a manual vacuum vent valve, and interconnect hose assemblies. In this system there are a number of individual components which are candidate SRU's due to the simplicity in being able to identify and isolate a faulty component and safely remove it. Because the gas supply module is likely to be changed out during each 90 day resupply flight, this element will have numerous opportunity for ground based refurbishment; therefore, it's elements are not considered SRU's. The gas control tray assembly, however, is a candidate ORU with all the elements in the tray as possible SRU's except for the tubing elements, which are best repaired in the ground environment. A cross over valve is provided between the GN2 and Argon loops to provide a redundant gas control loop within the tray. Loss of a regulator or outlet valve in an individual circuit would not necessarily cause total loss of system operation.

The GDS ORU's/SRU's in the core rack are listed in Table 3 and shown in Figures 26 - Figure 29 with key technical parameters for each item identified.

TABLE 3. GAS DISTRIBUTION SUBSYSTEM ORBITAL REPLACEMENT UNITS (ORU'S) AND SHOP REPLACEABLE UNITS (SRU'S)

ORU's	QTY	FIGURE
Gas Supply Module	1	26
Hose Assembly	1	27
Furnace Supply	1	
Vacuum Vent	1	
Contamination Electronics	1	28
GDS SRU's		
Filters	2	29
Pressure transducers	3	
Manual valves	2	
Solenoid Valves	3	
Regulators	2	
Check Valves	4	
QD's	3	
Indicator Lamps	6	
Panel Readouts	3	29

Note 1: All of the SRU's noted are located in the gas control assembly tray shown in Figure 29. Further details on each of the potential SRU's is given in Ref. 11.

Note 2: A primary power and data system harness has pig tail feeds to the GDS components. A major failure in these lines would necessitate a work around until the major scheduled overhaul. These are not considered practical ORU/SRU items.

4.1.4 DATA MANAGEMENT SYSTEM

The DMS components in the core rack are shown in Figure 13. This hardware is highly specialized equipment and will be considered for the most part box level ORU's. Some card level reconfiguration or repair is possible in several of the units. The Core Control Unit (CCU) and the Core Monitor and Control Unit (CMCU) could be such a unit if access to the boards in these boxes is straight forward and replacement can be accomplished within the target SRU time limits. Due to the criticality of these units to the availability of the SSFF system they will be be considered SRU's in this study. Other boxes could also be SRU's; however, since none of them is essential to the system availability, they will be put in the ORU (ground based spare) category for this study.

The DMS ORU's/SRU's in the core rack are listed in Table 4 and shown in Figure 30 - Figure 39 with key technical parameters for each item identified.

TABLE 4. DATA MANAGEMENT SUBSYSTEM ORBITAL REPLACEMENT UNITS (ORU'S) AND SHOP REPLACEABLE UNITS (SRU'S)

ORU's	QTY	FIGURE
Video Display/Keyboard	1	30
CDROM	1	31
Removable Hard Drive	1	32
High Density Recorder	1	33
HDR Electronics	1	34
Video Processor	1	35
CPC Stimulus	2	(w/Pwr Cd Bks)
Bus Couplers	5	36
Cable Assembly		37
1553 Bus	1	
802.3	1	
SCSI	1	
Station Interface	3	
RS-422	1	
Video Telemetry	2	
(Core Monitor/Ctrl)	1	
Keybd/Display	1	
DMS SRU's		
Core Control Unit	1	38
Core Monitor & Control Unit	1	39

Note 1: A primary power and data system harness has pig tail feeds to the DMS components. A major failure in these lines would necessitate a work around until the major scheduled overhaul. These are not considered practical ORU/SRU items.

4.2 EXPERIMENT RACK ORU'S

The integrated packaging design of the SSFF Experiment Racks is shown in Figure 40. As can be seen in the figure, the subsystem support equipment is grouped almost entirely behind the furnace enclosure (IFEA) making access to this equipment from the front impossible. The rack will have to be rotated out and one or more of the side or rear panels removed in order to gain access to the equipment. The SSF program has a limit on removal of only one panel for ORU's; however they do not consider the face plates as panels. This rack is unique and may have to seek a waiver on that requirement. Access to each equipment item and the proposed packaging arrangement will be studied thoroughly with the SSFF mock up and it is likely that a number of changes will be made before the layout is finalized during the Phase C/D.

A special support frame (Figure 41) has been added to back of the basic rack structure to augment the mounting features of the four corner posts. The Furnace Control Unit (FCU), Furnace Acquisition Unit (FAU), and Essentials Power Supply boxes are the primary equipment items mounted to this frame. The other subsystem hardware items are dispersed around the rack in various unique mounting arrangements. These packaging features will be brought out in discussing the ORU selections for the experiment module in the following sections.

4.2.1 EXPERIMENT RACK TCS ORU's

The TCS elements in the experiment racks are shown on the schematic of Figure 3. Because the fluid must traverse a long circuit in the rack, the TCS components are located in several different positions. The two main features in the loop are a coolant inlet control assembly (Figure 42) and a coolant return control assembly (Figure 43). These assemblies are aluminum frames in which are mounted control valves and flow monitoring devices for diagnosis and control of inlet and return fluid conditions. The two frames are attached to the rear corner posts below the electronics boxes. The other components in the Experiment Rack TCS system are packaged in coolant line assemblies (flex hose) with OD's at either end. The most significant of these being the line containing the loss of coolant accumulator at the furnace outlet. The two coolant control frames and other elements are listed in Table 5 as Experiment Rack TCS's ORU's.

TABLE 5. EXPERIMENT RACK TCS ORU'S

ORU	QTY	FIGURE
Coolant Inlet Control Assy	1	42
Coolant Return Control Assy	1	43
Cold Plates	3	18
Accumulator Assy	1	44
Hose Assemblies	6	45

4.2.2 EXPERIMENT RACK PCDS ORU's

The PCDS components in the experiment rack are shown in the schematic of Figure 4. They consist of the furnace junction box, the essentials power supply, the furnace power distributor, current pulsing equipment, and the associated power distribution cables. Each one of these elements is a potential ORU. Table 6 lists the Experiment Module PCDS ORU's. The most likely scenario for a PCDS ORU component change out would be due to its premature operational failure and not for a furnace reconfiguration. In the case of reconfiguration the whole rack assembly will most likely be returned to earth. The planned mission for a particular experiment rack along with the expected service life estimates for the candidate ORU elements would determine their logistic status; i.e., stored on orbit or stocked on the ground for immediate manifest or at the preprogrammed preventative maintenance interval.

TABLE 6. EXPERIMENT RACK PCDS ORU'S

ORU	QTY	FIGURE
Furnace Junction Box	1	46
Essentials Power Supply	1	23
Furnace Power Distributor	1	47
Current Pulsing Equipment	TBD	TBD
Cable Assemblies	TBD	TBD

4.2.3 EXPERIMENT RACK GDS ORU's

The GDS components in the Experiment Rack are shown in the schematic of Figure 5. There are a number of components shown in this GDS schematic related to pressure and contamination control that may be deleted as the SSF/SSFF design is developed further. For this report, however, all of the elements shown are assumed to exist at this time and to be potential ORU/SRU's. There has been some modular packaging or grouping made of the schematic elements that would allow some GDS components to be removed in pretested blocks with QD's or quick clamps at either end if desired. The gas supply valve assembly, the relief valve manifold, and the vacuum valve manifold would be such typical modular units. These elements are ORU's while the components within the assembly could also be SRU's. The other components in the GDS could also be removed individually within the time constraints set up for on orbit repairs, assuming no concerns existed over contamination in the vent system that would prevent opening that system. Table 7 lists the Experiment Rack GDS ORU/SRU's.

TABLE 7. EXPERIMENT RACK GDS ORU/SRU'S

ORU	QTY	FIGURE
Relief Valve Manifold SRU: Relief Valves - 2 Press Sensor - 1	1	48
Gas Supply Valve Assy SRU: Solenoid Valve - 1 Check Valve - 1 Hose Assy - 2 QD's - 2	1	49
Vacuum Filter	1	50
Vacuum Valve Manifold SRU: Vacuum Valves - 2 Latch Valves - 3	1	50
Vacuum Pressure Sensor	1	51
Vacuum Pump	1	52
Storage Vessels	2	53
Contamination Sensor	(1)	TBD
Vacuum Accumulator	1	TBD
Hose Assemblies	TBD	TBD

4.2.4 EXPERIMENT RACK DMS ORU's

The DMS components in the Experiment Rack are shown in the schematic of Figure 6. They consist of the Furnace Control Unit, the Furnace Acquisition Unit, the Distributed Core Monitor Unit, bus couplers, and the various DMS signal and control cable assemblies. As was assumed for the Core, these components are taken as ORU's at the box level, with the possibility of board level repair in the FCU and FAU, making them SRU's. Because of the safety aspect of the DCMU this unit will be kept as an ORU only. Further analysis will be needed of all the components designated as SRU's in the detail design phase to determine if appropriate reverification of system performance can be made following a board level repair. Table 8 lists the Experiment Rack DMS ORU/SRU's.

TABLE 8. EXPERIMENT RACK DMS ORU/SRU'S

ORU	QTY	FIGURE
DCMU	1	TBD
Bus Coupler	3	36
Cable Assemblies	TBD	TBD
SRU		
Furnace Control Unit	1	54
Furnace Acquisition Unit	1	54

4.3 FURNACE MAINTENANCE / RECONFIGURATION ORU'S

A study has been made in Reference 10 of the various issues related to maintenance and possible reconfiguration of a furnace module on orbit. The only elements of that study which are relevant to this report are the reliability data and the components/ operations which have been identified for ORU's. Table 9 given below has been taken from that report. It indicates the elements of the furnace module considered the least reliable and proposes their replaceable on orbit. Since a special tent must be erected to perform some of the repair operations listed, it remains to be seem if the SSF Program will permit some of these tasks to take place. For this study it will be assumed that a decision to manifest an individual ORU element would be made real time with a reported failure. As a worst case, TBE recommends the program plan into the SSFF support logistics program change out of the furnace IFEA's once a year, and the full experiment module rack every four years. If this level of STS flight support (reference Figure 58) could be approved it would preclude any on orbit repairs except for those which can be performed through the sample access port. This will obviously inflate the facility logistical resupply mass figures furnished in Figure 57 and the SSF program may not have the up/down mass available. A cost and technical trade off of resupply factors versus the on orbit repair operations would be required to determine the best program approach.

TABLE 9 - MODULE 1 ORU ANALYSIS

No.	ORU	Down Time (hours)	Tools and Supplies	Notes
1.	One sample	40	PGBX • Connector Wrench • Storage cannister	Starting with a hot furnace
2.	All samples	37	• PGBX • Connector Wrench •Two storage cannisters	Starting with a cold furnace
3.	Indexing motor	34	• PGBX • Connector Wrench • Storage cannister	Fault detected when attempting to index samples
4.	Carousel	137	• Cleanroom tent • Bunnysuit • Hand tools • Calibration tool • Test hoses/cables	Requires cleanroom conditions
5.	RFM: • replace • reconfigure	 162 TBD	• Cleanroom tent • Bunnysuit • Hand tools • Calibration tool • Test hoses/cables	RFM can be reconfigured without removing (changing adiabatic zone height and/or adding deleting heat extraction plate)
6.	RFM plus carousel	TBD	• Cleanroom tent • Bunnysuit • Hand tools • Calibration tool • Test hoses/cables	Necessary when changing to new type of thermacouple
6.	FTS drive belt	TBD	• Cleanroom tent • Bunny suit • Hand tools • Test hoses/cables	Can be removed from side
7.	Clear aisle for leak repair	goal: 60 sec		Worst case: IFEA disassembled

Assumptions:
1. Times shown do not include fetch, stow or break times.
2. SACAs are exchanged via SSF Portable Glovebox (PGBX).
3. Cleanroom tent & bunny suit must be used when IFEA is opened.

Hand Tools: Torque wrench, ratchet, 9/16 socket, extension - 10 in., extension - 3 in., Allen wrenches - 0.156 and 0.190 in., tube wrenches - 3/8 and 1/2 in., diagonal cutters

Training: Familiarity with drawings and procedures; training in the use of torque wrenches, staking and safety wire; practice in ORU changeout utilizing GCEL system.

4.4 CORE COMPONENT RELIABILITY DATA

An effort has been made as part of this study to identify the Mean Time Between Failure (MTBF) of the purchased hardware components selected by the various subsystems and the manufactured ORU assemblies which comprise the SSFF facility. It is impossible to be completely accurate in any type of reliability analysis, and particularly difficult, since almost all of the SSFF hardware selected has either not been developed, is currently undergoing development, or has not been used extensively in space before. The numbers given in Table 10 below may appear low in some cases and as discussed later, an effort has been made to take certain system duty cycle relief factors into consideration as well as to normalize the numbers with space station estimates. Table 11 shows a comparison of the MTBF estimates given in Reference 7 for space station hardware which is judged to be comparable to the SSFF components noted. The station factors have not taken into account the quantity failure factors and an additional column has been furnished to show this effect.

TBE made a concerted effort to contact all the hardware vendors identified by the subsystem designers; however, very few had definite reliability data to feed into the analysis. In most cases the estimates shown are based on hand book values or were vendors best guesses, in those cases where they were willing to venture a number. MIL-HDBK-217E was used as the principle data source of failure rates for electrical and electronic parts/ components. Failure rates for mechanical and electromechanical components were obtained from the Nonelectronic Parts Reliability Data (NPRD-91) published by the USAF Rome Air Development Center. The normalized failure rate data has been used to construct the spares stocking and logistic resupply plans discussed in Section 5.

Notes To Table 10:

1.) The failure rates noted are based on 1,000,000 hours of operation. The quantity failure rate is simply the individual part rate multiplied by the number of parts in the system. The MTBF is 1,000,000 hours divided by the quantity failure factor.

2.) The core rack system are assumed to be overhauled after 10 years of service to like new condition; therefore, component MTBF's greater than 10 years will not be tracked further. This does not mean they would not be ORU's and need to be stocked, but it does indicate their in service failure is much less likely and where degraded system performance could be tolerated for a period of time they could be manifested on an as needed basis.

3.) The core junction boxes are items which would very likely be changed out each time a furnace is changed. Their life will therefore be tracked with the experiment rack hardware.

TABLE 10 - CORE COMPONENT RELIABILITY ESTIMATES

Gas Distribution:	Qty	Failure Rate	Qty Failure	MTBF (hrs)	MTBF (yrs)
QD's	5	0.445	2.224	449,741.4	> 10.0
Filters	2	7.840	15.680	63,775.5	7.3
Press Sensors	3	23.260	69.780	14,330.7	1.6
Check Valves	4	0.445	1.778	562,429.7	> 10.0
Manual Valves	3	10.870	32.610	30,665.4	3.5
Solenoid Valve	4	36.370	145.480	6,873.8	0.8
Regulators	2	2.860	5.720	174,825.2	> 10.0
Thermal Control:					
Heat Exchanger	1	7.880	7.880	126,903.5	> 10.0
Pump Package	1	83.330	83.330	12,000.5	1.4
QD's	37	0.445	16.450	60,790.3	6.9
Temp Sensors	5	0.107	0.535	1,870,907.4	> 10.0
Press Sensors	3	23.260	69.780	14,330.8	1.6
Manual Valves	2	10.870	21.740	45,998.2	5.3
Flow Ctl Valves	2	107.350	214.700	4,657.7	0.5
Flow Meters	2	24.790	49.580	20,169.4	2.3
Cold Plates	10	7.880	78.800	12,690.4	1.5
Check Valves	2	9.460	18.920	52,854.1	6.0
Shut Off Valves	2	36.370	72.740	13,747.6	1.6
Power Cond/Dst:					
Manual Breaker	2	0.076	0.152	6,579,000.0	>10.0
RPCM	2	25.722	51.444	19,440.1	2.2
Dist. Box	1	51.444	51.444	19,440.1	2.2
Ess. Pwr Sply	1	2.858	2.858	349,895.0	> 10.0
Cond. Banks	2	36.000	72.000	13,888.9	1.6
Junction Box	2	(Note 3)	-	-	-
Data Managem't:					
Computers	4	50.213	200.852	4,978.8	0.6
Hard Drive	1	50.213	50.213	19,915.0	2.3
Tape Recorder	1	106.383	106.383	9,400.0	1.1
Playback	1	106.383	106.383	9,400.0	1.1

TABLE 11 - COMPARISON OF SSF AND SSFF FACTORS

Component	SSF MTBF	SSFF MTBF	Normalized
Solenoid Valves	333,300 (hrs) (83,325)	6,874 (hrs)	20,622 (hrs)
Pump Package	31,700	12,000	17,520
Heat Exchanger	278,000	126,904	126,904
Flow Ctrl Assy*	48,300 (16,100/8050)	4,658	14,330
Cold Plates	4,000,000 (400,000)	12,690	25,380
RPCM	100,000 (50,000)	19,440	38,877
Computers	39,000 (9,750)	4,979	9,750
Tape Recorder	6,900	9,400	9,400

Notes:

1.) The SSF numbers in parenthesis is the individual MTBF factor divided by the number of components of that type in the SSFF system.

* - The SSF Flow Control Assembly consists of a flow control valve, a flow meter, and a pressure or a temperature sensor all in one unit. This closely approximates the SSFF flow control packages in Figures 16 and 17. The numbers in parenthesis represent three components per assembly (16,100) and two assemblies per rack (8050). The MTBF for a unit like these is difficult to predict since the other components in the package other than the valves had fairly high factors, therefore a normalized factor has been assumed biased toward the higher component and station numbers.

2.) The MTBF for GDS solenoid valves has been increased by a factor of three based on the duty cycle being much lower for the valves than the rest of the SSFF system. The SSF MTBF is assumed to be for 30 year life valves whse expense may not be justified for the SSFF.

3.)The other elements in the table have been normalized upward by a conservative factor less optimistic than the station estimates. The others which remained unchanged are simply noted for comparison.

4.5 EXPERIMENT RACK COMPONENT RELIABILITY

The SSFF subsystems have an extensive complement of equipment which must be located in the experiment racks for the control and safe operation of the experiment furnaces. The schematics for the subsystems are given in Section 5.0 and the list of experiment rack potential ORU's is given in Section 4.2. The reliability study of these components follows very closely that made for the core subsystems in Section 4.4. In fact, many of the same components are found in each rack; therefore, only the normalized data on experiment rack ORU's will be presented here. As in the core rack where the MTBF component life of less than ten years was of concern, those components with MTBF estimates greater than the four year in-orbit service life of an experiment rack will not be discussed. The facility logistic planning data given in Figure 58 shows that the racks are changed out every four years at which time the experiment rack components would be refurbished before returning to service. The data given in Table 12 has been compiled with that from Tables 10 and 11 to formulate an approximate estimate to the total facility resupply mass which would include the routine facility operational materials and equipment and the repair or maintenance equipment in the form of ORU's. This compiled data appears in Figure 57.

TABLE 12 - EXPERIMENT RACK COMPONENT RELIABILITY

Gas Distribution:	Qty	Normalized MTBF	MTBF (yrs)
Filter	1	N/A	2.0
Solenoid Valve	1	29,495 (hrs)	3.1
Vacuum Valves	2	14,330	1.6
Valve Manifold	1	20,633	2.3
Thermal Control:			
Flow Ctrl Assy	2	14,330	1.6
Cold Plates	3	25,380	2.9
Power Cond/Dst:			
Power Distr.	1	38,877	>4.0
Data Managem't:			
Computers	3	13,000	1.5

Note: The other ORU candidates listed in Section 4.2 and not shown in this table have MTBF estimates in excess of the required experiment rack four year life.

5.0 CANDIDATE ORU DATA

This section contains all the figures of candidate ORU's referred to in the previous analysis of subsystem hardware. The figures indicate the approximate hardware size and weight, less any packaging which would be necessary to transport the assembly or components as ORU's. A good many of the items shown are entire trays which, in some cases, could fit within the envelope defined for SSF stowage rack drawers, reference Figure 55. Other SSFF ORU trays are oversized or are so unique in design that a special transport frame would be necessary to hold the assembly and properly support its load reactions for the launch and landing environments. These frames would be designed to interface to the same rail system provided in the SSF stowage rack (assuming this same rack configuration will be used on a shared basis to manifest numerous small station and payload resupply items). The stowage drawers in a portion of the rack would be temporarily removed for the flight in which the SSFF tray needed to be delivered. If the ORU is to be stored on orbit and not immediately changed out, then the same interface mounting frame may have to be temporarily located in a LAB stowage rack unless some other method of temporarily securing the assembly can be found until the ORU is changed out.

Table 13 and Figure 56 are a preliminary list of the storage items planned for initial deployment of the SSFF system (core and CGF). Additional storage space would be required as operational life is accumulated on the facility and the second experiment module is manifested. The worst case of the resupply mass estimate from Figure 57 was used to construct the approximate maximum on orbit storage space need shown in Table 14. There are two times in the facility histogram (at 3.5 and 7.0 years) when this storage maximum is reached. A slightly smaller volume but greater weight event occurs at the 9.0 year point. Figure 57 shows how the resupply mass would vary over the first ten years of the facility life based on the many assumptions previously stated. It is also assumed, for this chart, that the system is initially deployed with only one experiment module and the second is added two years later. The facility would continue to operate with the two experiment modules up till the 8.0 year point , for this report, it is assumed to be more economical to finish out the remaining core two years with only one experiment rack. The experiment rack resupply mass shown in the chart is only for the distributed subsystem equipment, any furnace peculiar ORU's have not been included. Figure 58 is included to show the facility phased deployment history (total mass) as a graphic representation of the STS cargo mass which would be associated with the change out of furnace modules once a year and the change out of the entire experiment racks every four years.

TABLE 13 - INITIAL FACILITY SPARES / EQUIPMENT LIST

ITEM	SIZE (cm)	WEIGHT (kg)
Tape Recorder	15.2 x 42.8 x 64.5	41.0
Gas Supply Module	25.8 x 48.3 x 66.4	22.5
TCS Coolant Pump	24.5 x 40.6 x 50.7	23.5
Sample Cartridge Tray	13.3 x 48.3 x 76.2	14.9
Tools, Test Eq, & Misc	26.7 x 48.3 x 76.2	TBD

Note: Reference Figure 56 for a graphic representation of this spares / equipment storage list.

TABLE 14 - WORST CASE ON ORBIT STORAGE ESTIMATE

ITEM	SIZE (cm)	WEIGHT (kg)
Tape Recorder	15.2 x 42.8 x 66.4	41.0
Gas Supply Module	25.8 x 48.3 x 66.4	22.5
TCS Coolant Pump	24.5 x 40.6 x 50.7	23.5
Sample Cartridge Tray #1	13.3 x 48.3 x 76.2	14.9
Sample Cartridge Tray #2	13.3 x 48.3 x 76.2	14.9
Tools, Test Eq, & Misc	26.7 x 48.3 x 76.2	TBD
Core Coolant Ctrl Assy	17.8 x 39.9 x 54.6	12.5
Pwr. Cond. Bank	24.1 x 39.9 x 63.5	23.6
Exp Rack- Clt In Ctrl Assy	20.3 x 25.4 x 38.1	6.2
Exp Rack- Vacuum Valve	10.1 x 10.1 x 20.3	2.0
Exp Rack- Computer	22.2 x 21.6 x 40.6	29.0
Totals:	0.512 cu meters	190.1

Note: Reference Figure 57. Data taken from 3.5 and 7.0 year operating points with the addition of a coolant pump which is stored as a permanent spare. Chart assumes the ORU's could not all be changed in the time frame of the resupply vehicle visit; therefore the removed hardware is stored for 90 days before return.

SPACE STATION FURNACE FACILITY(SSFF)

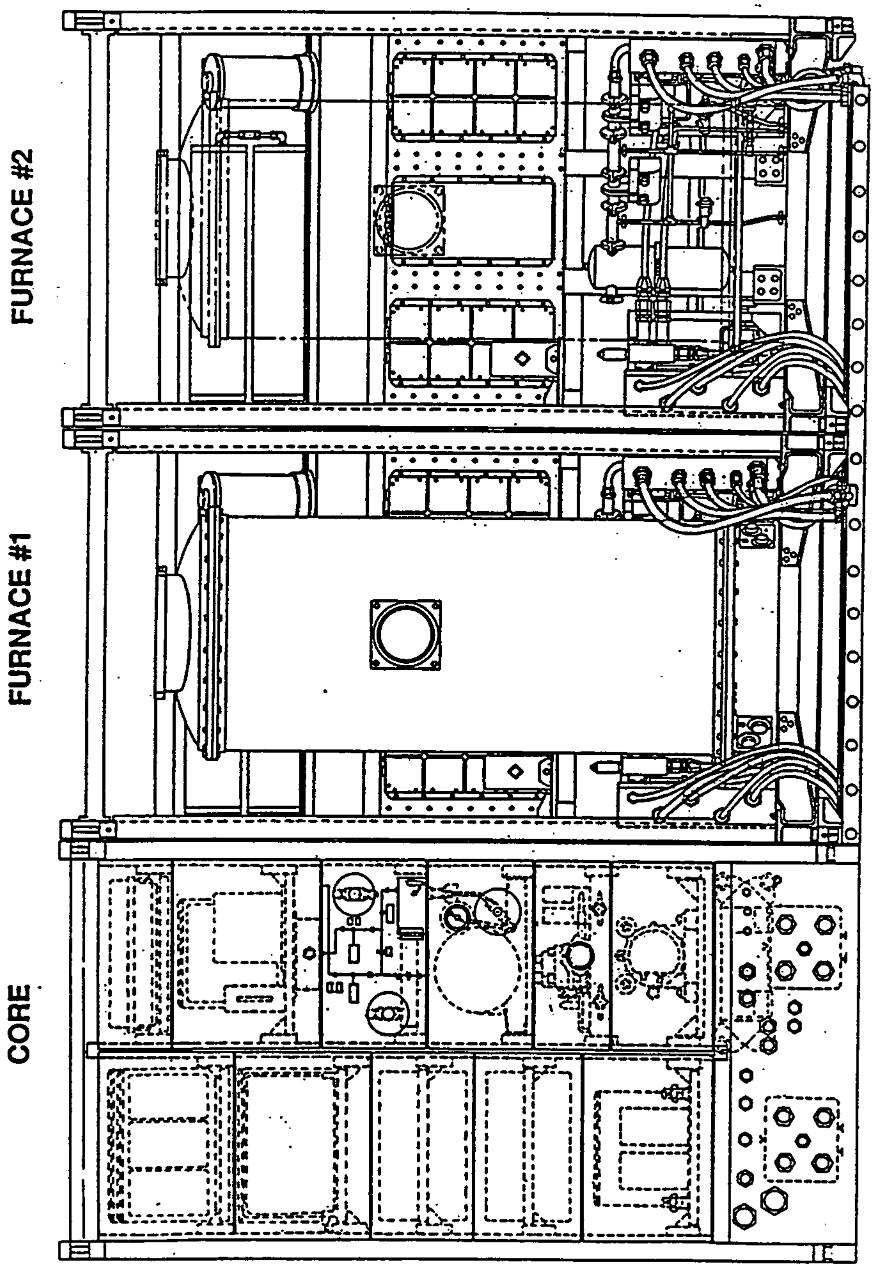


FIGURE 1

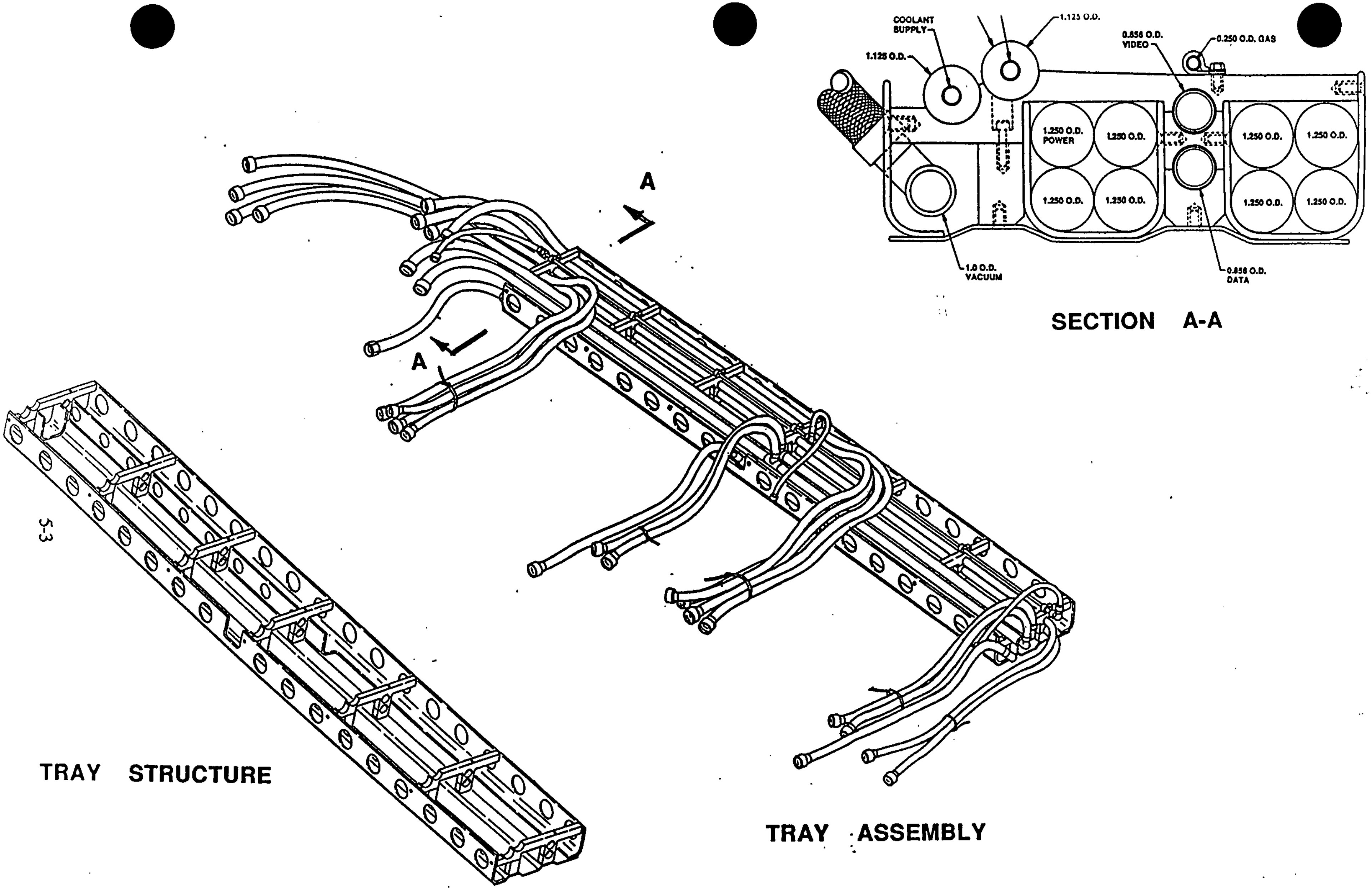
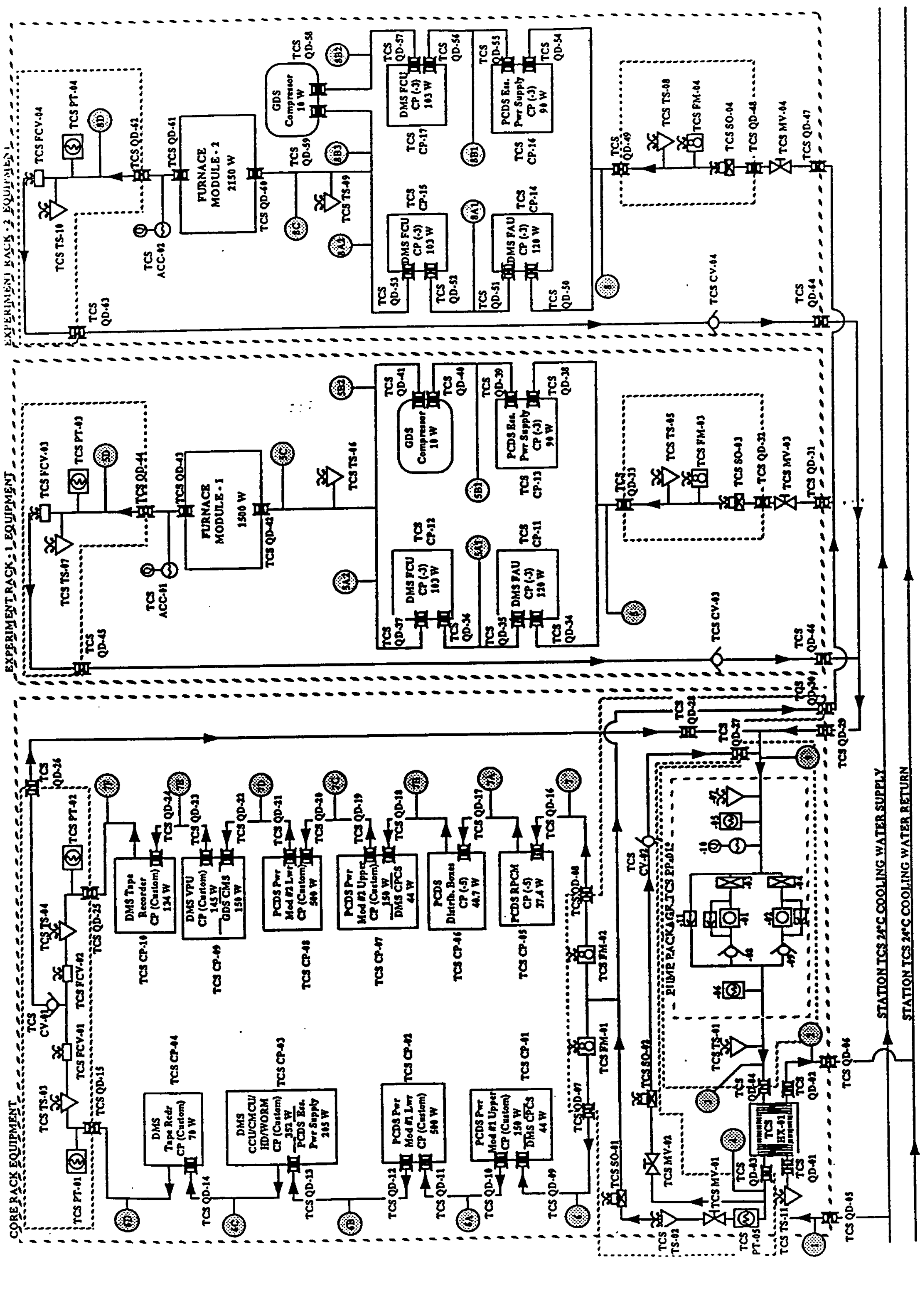


FIGURE 2

SSFF INTERCONNECT TRAY

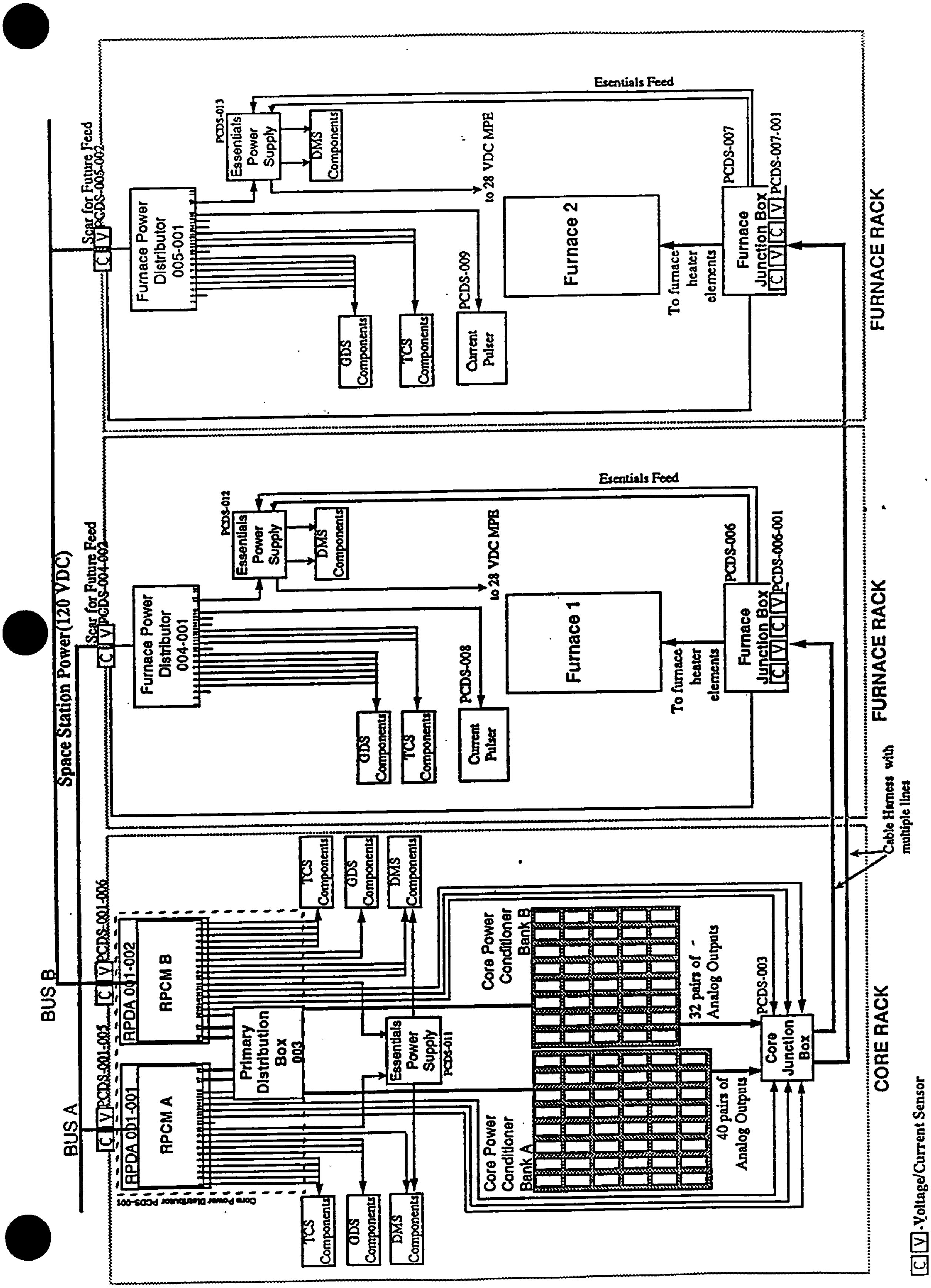


* PUMP PACKAGE COMPONENTS ARE NUMBERED TCS PP-01-XX, BUT ONLY -XX IS SHOWN ON SCHEMATIC FOR CLARITY

UPDATED 3/27/92

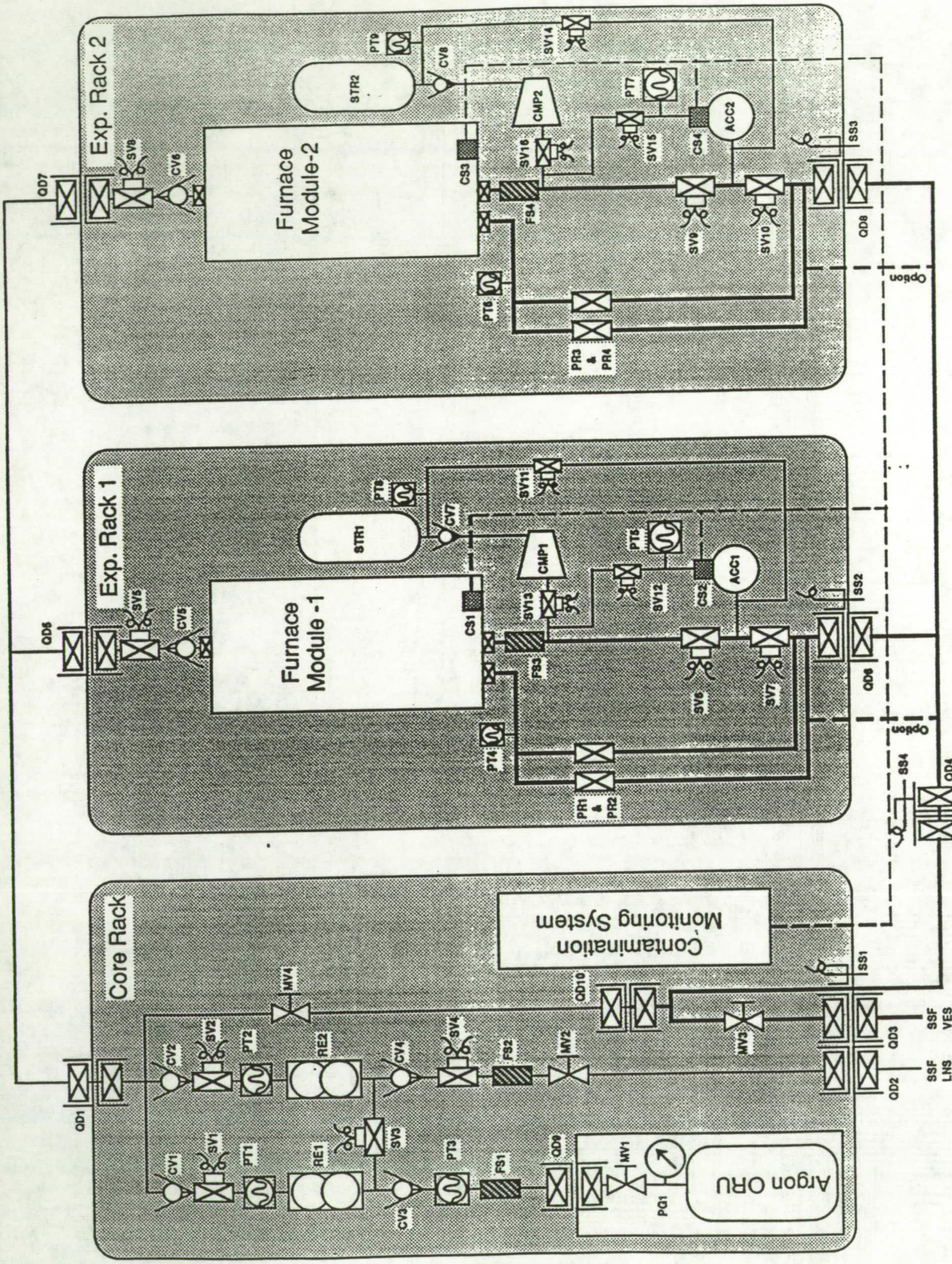
SSFF Thermal Control Subsystem Schematic

FIGURE 3



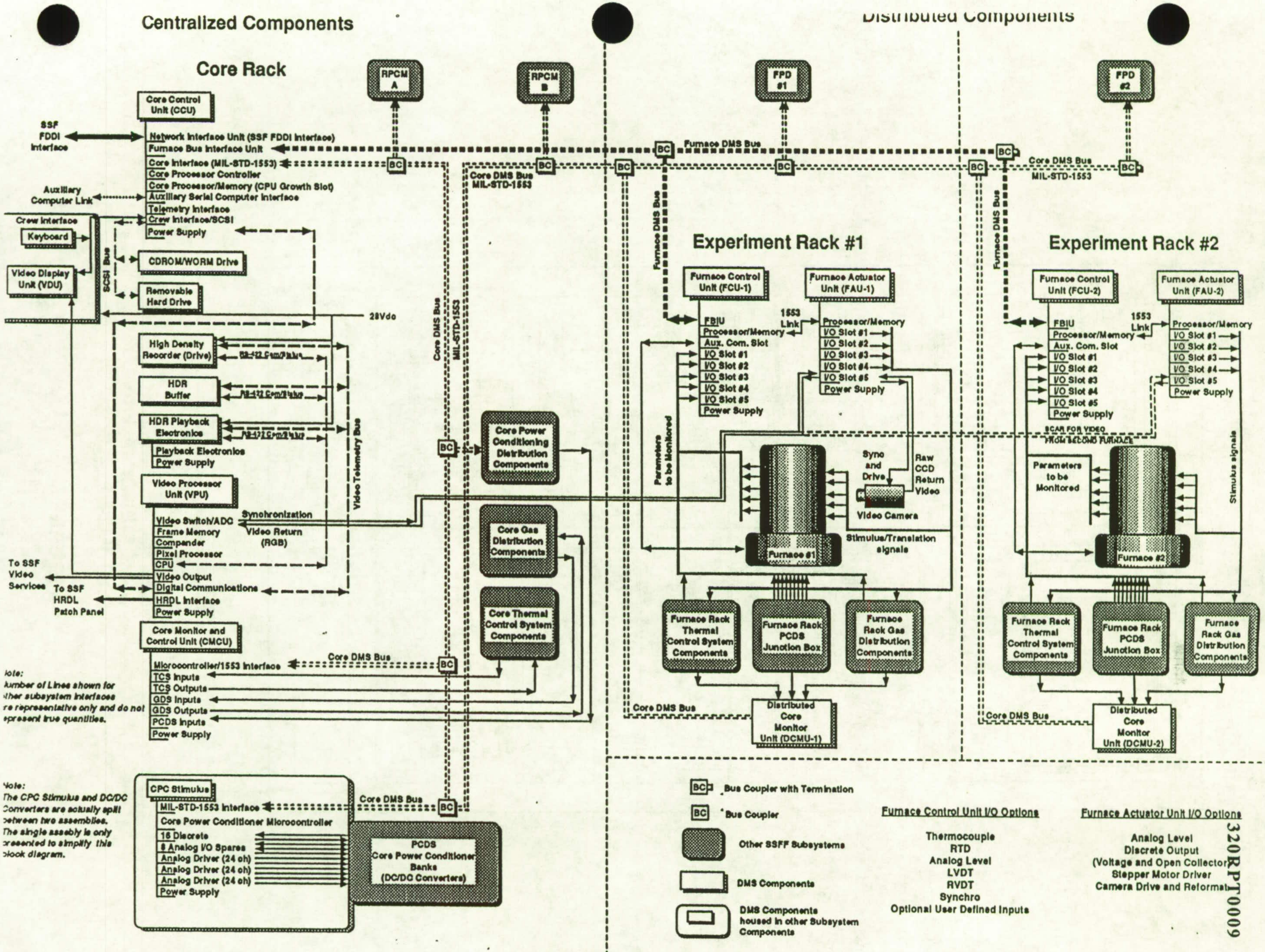
PCDS BLOCK DIAGRAM

FIGURE 4



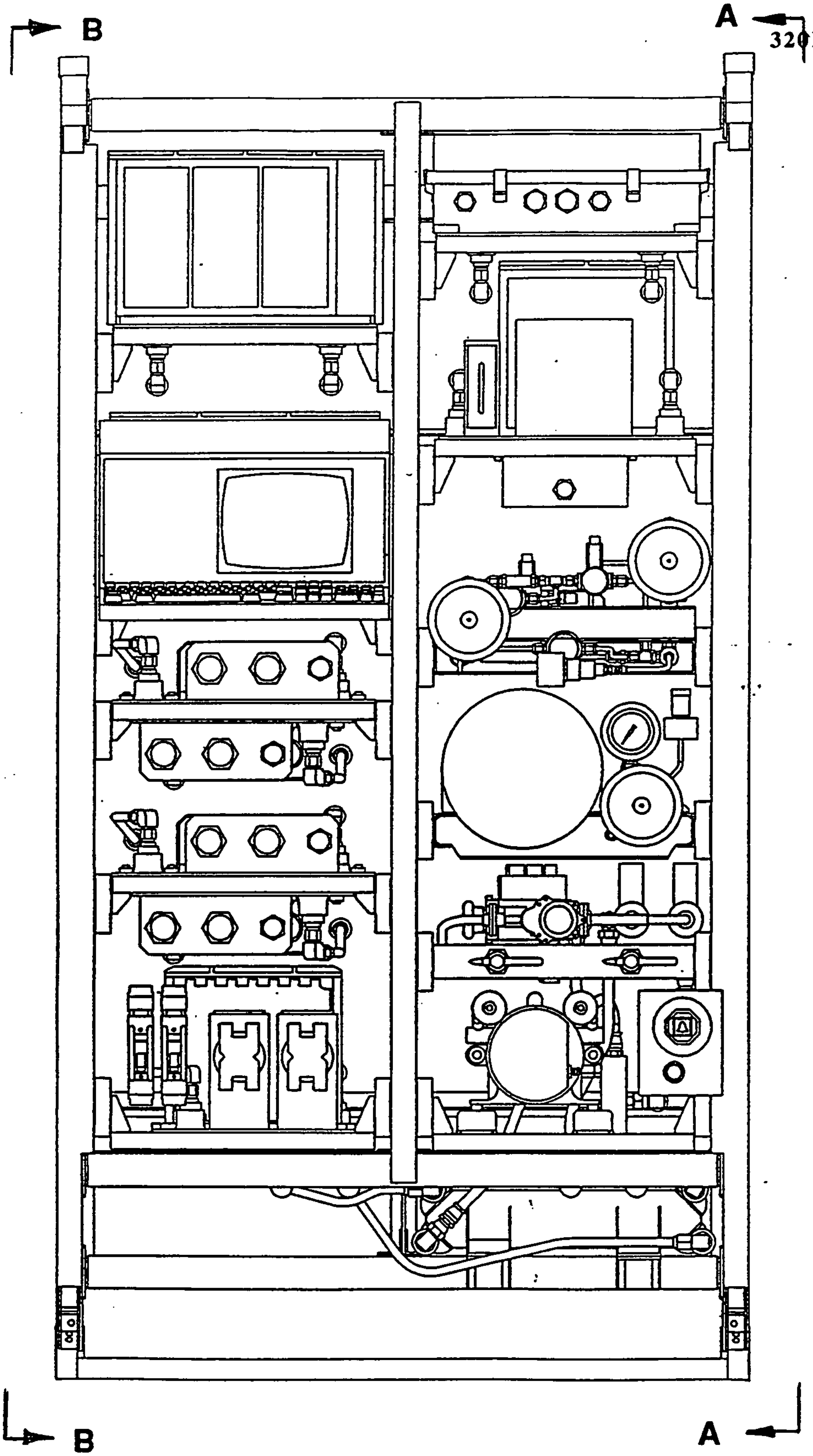
GDS schematic with compressor controlled pressure option

FIGURE 5



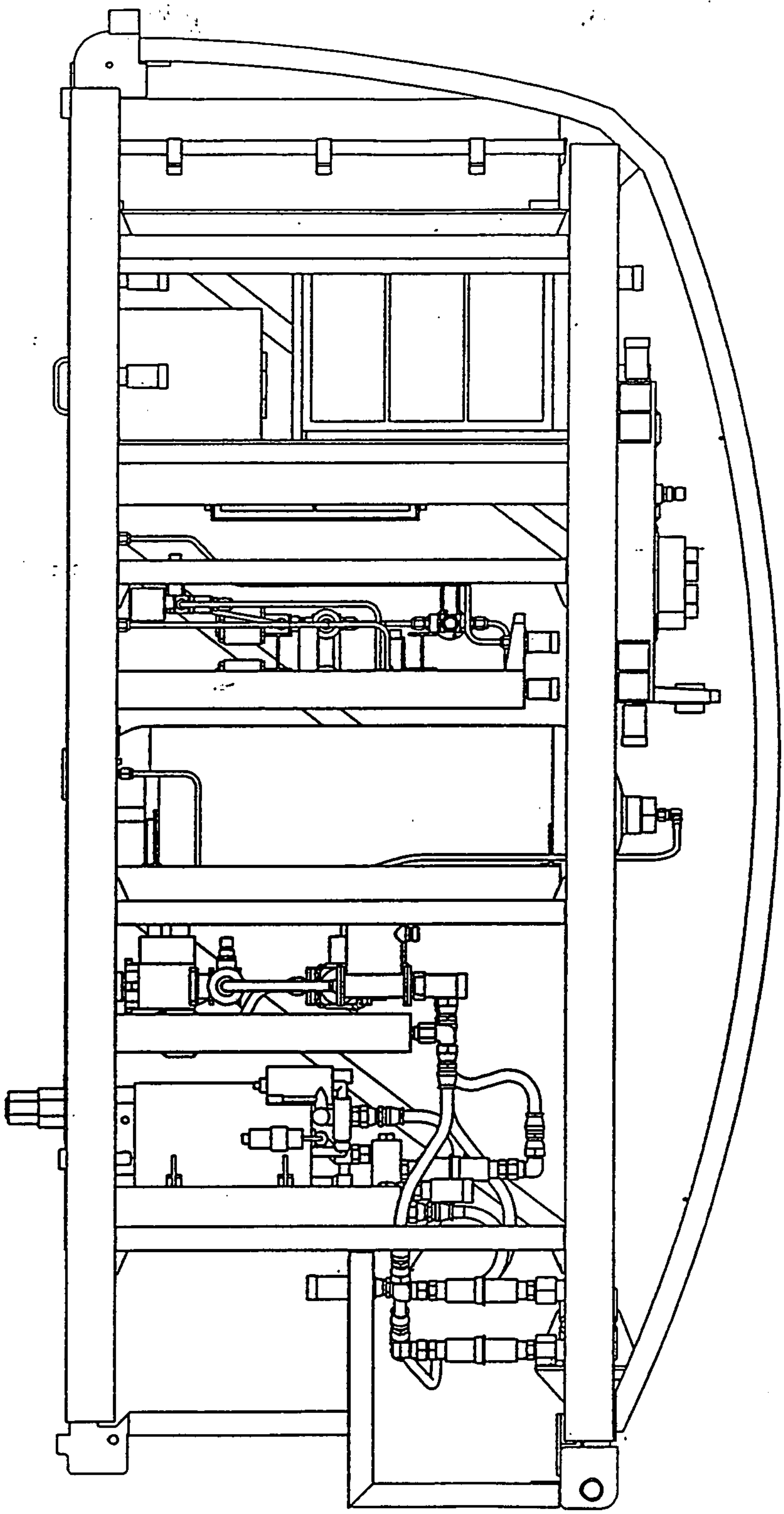
320RPT0009

FIGURE 6



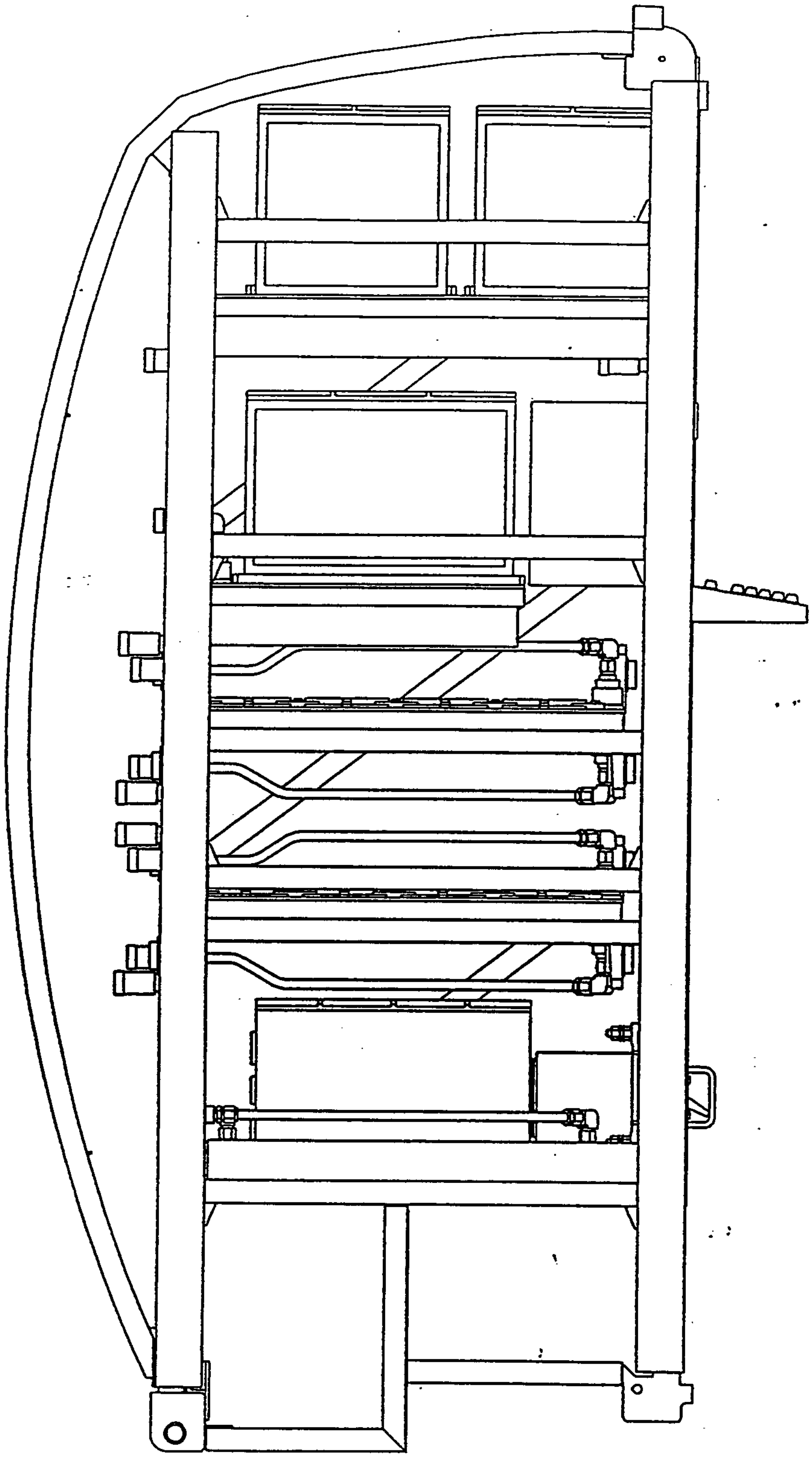
CORE RACK - FRONT VIEW
CAD MODEL

FIGURE 7



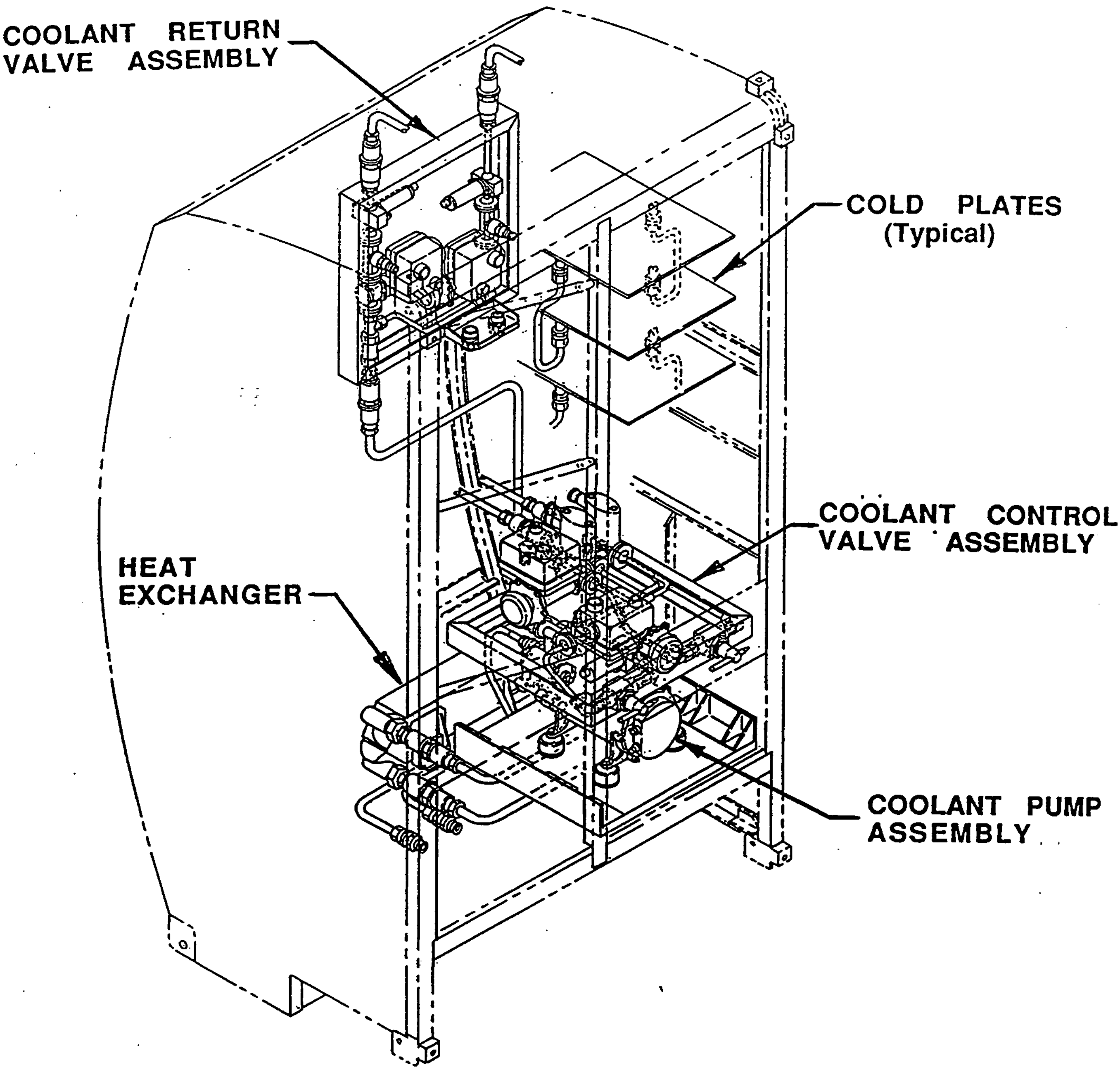
CORE RACK - SIDE VIEW A-A
CAD MODEL - LEFT BAY

FIGURE 8



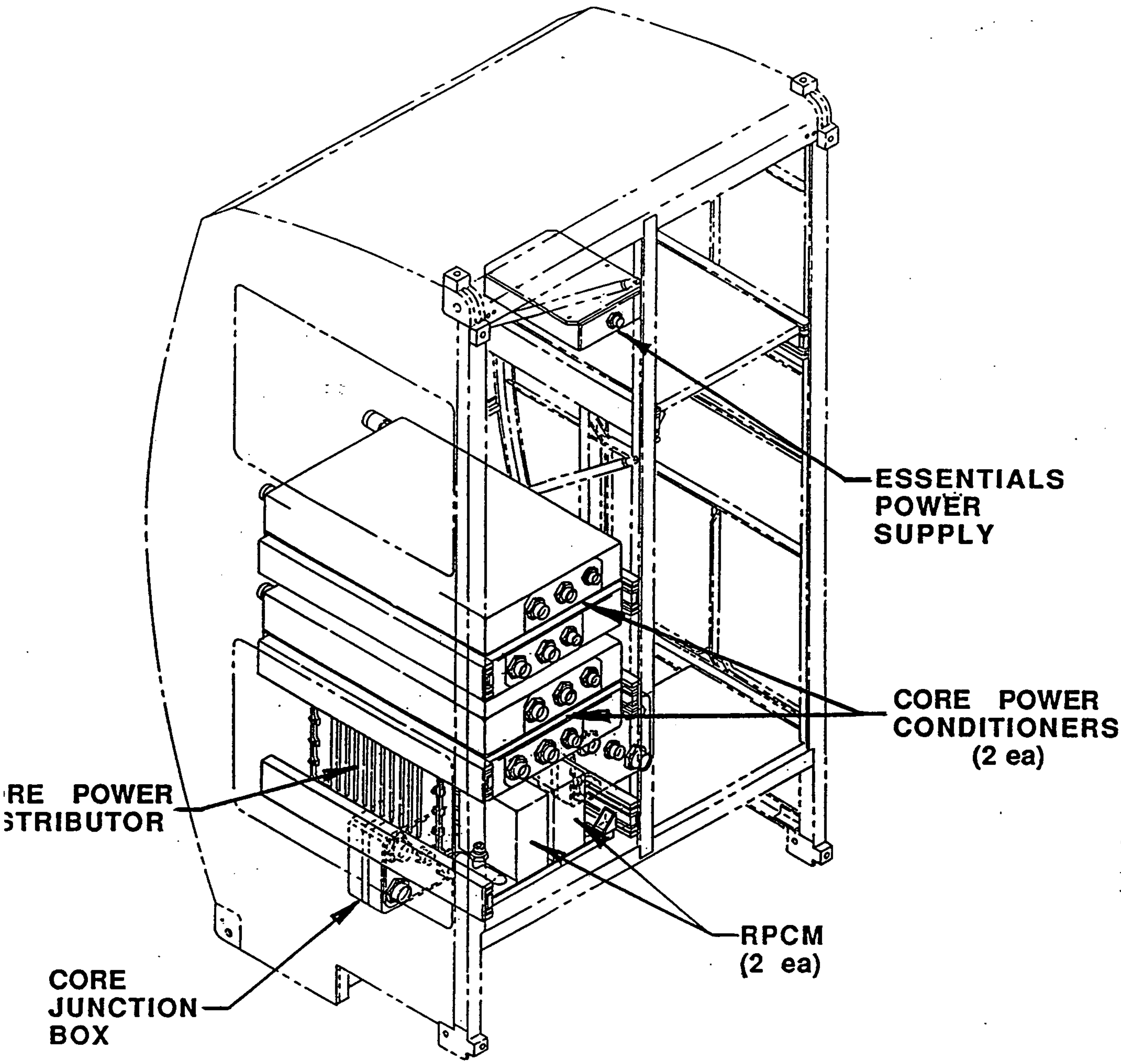
CORE RACK - SIDE VIEW B-B
CAD MODEL - RIGHT BAY

FIGURE 9



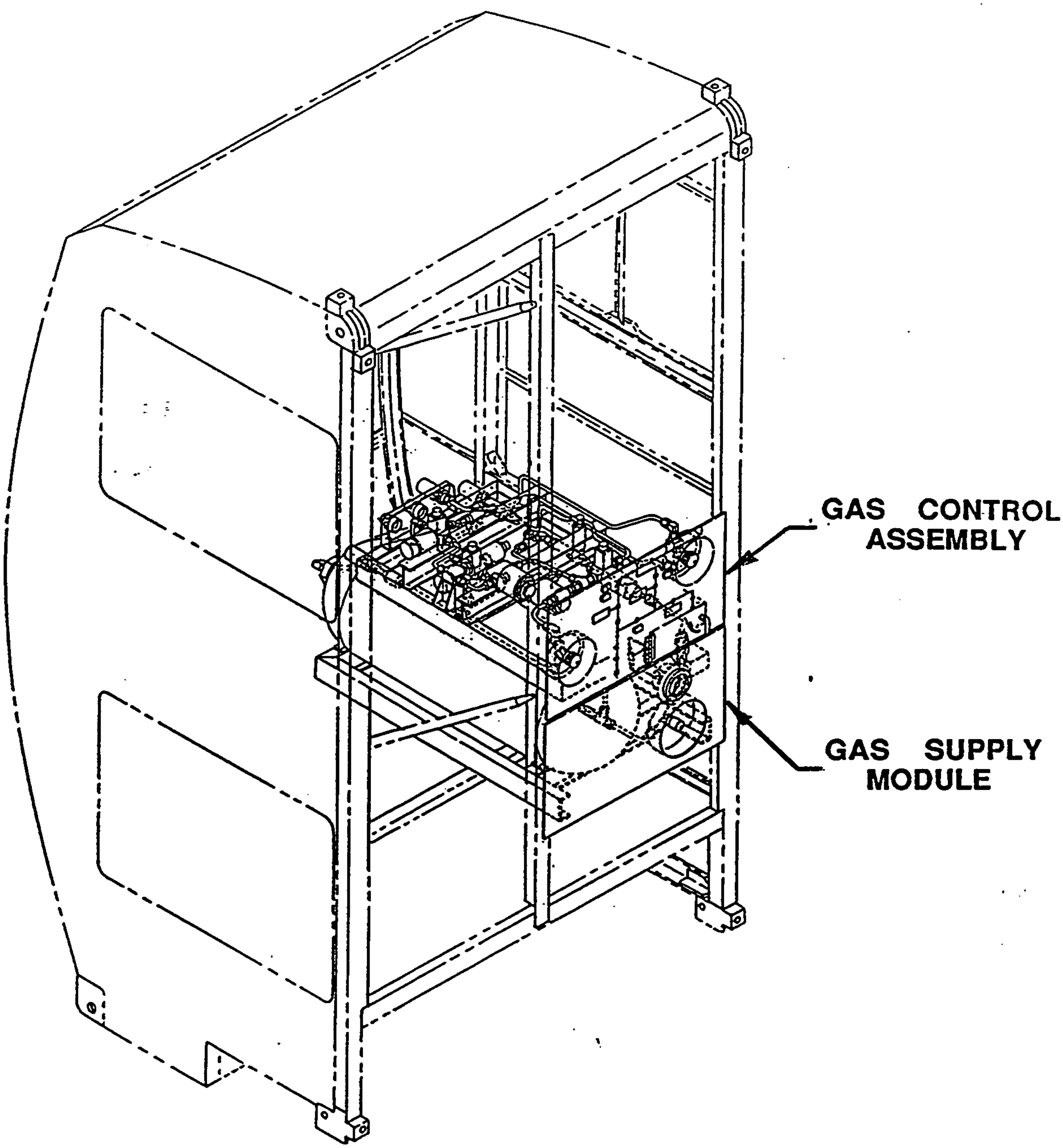
THERMAL CONTROL SUBSYSTEM (TCS)

FIGURE 10



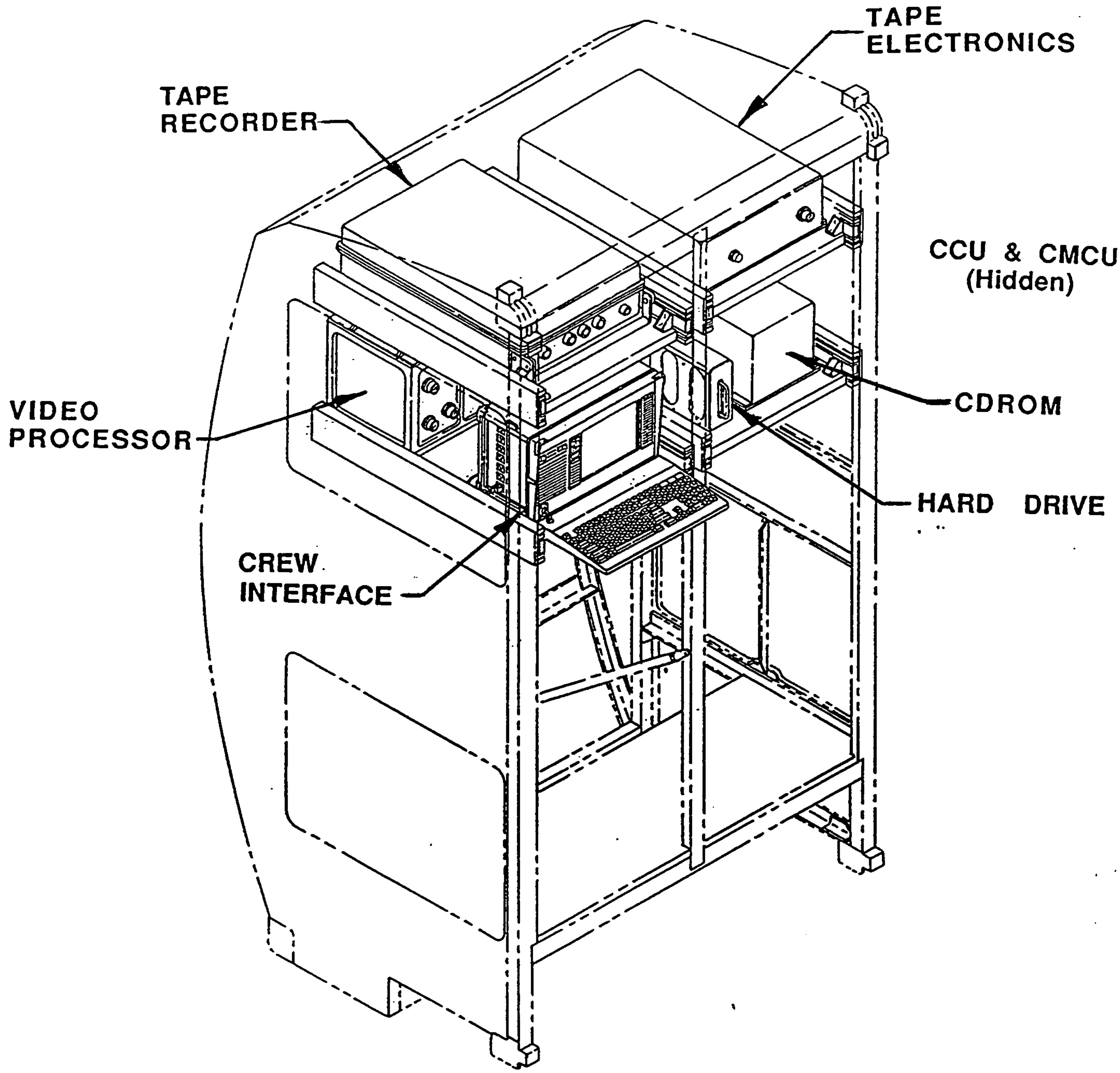
POWER CONDITIONING & DISTRIBUTION SUBSYSTEM (PCDS)

FIGURE 11



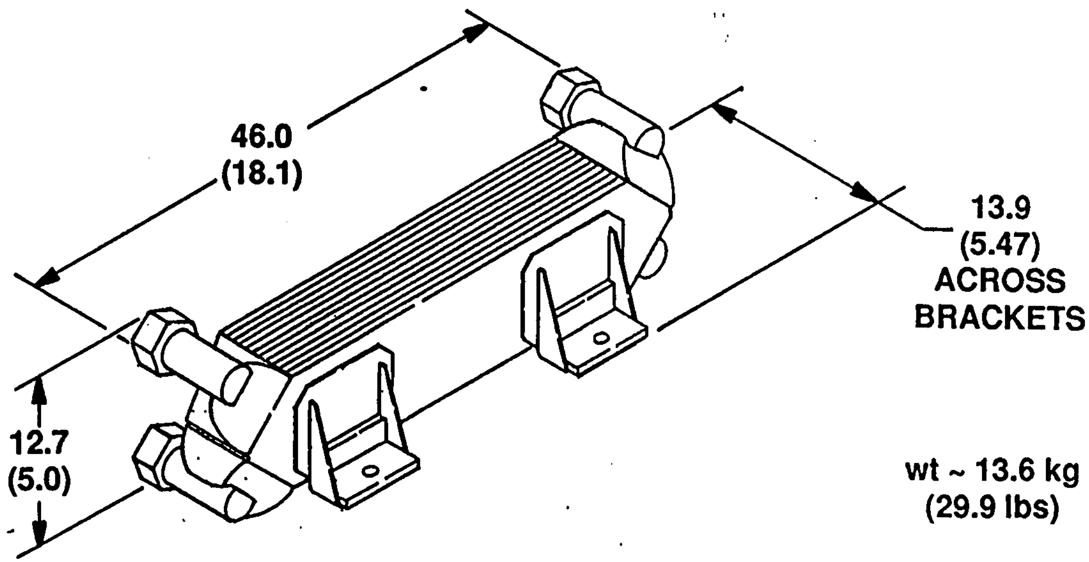
GAS DISTRIBUTION SUBSYSTEM (GDS)

FIGURE 12



DATA MANAGEMENT SUBSYSTEM (DMS)

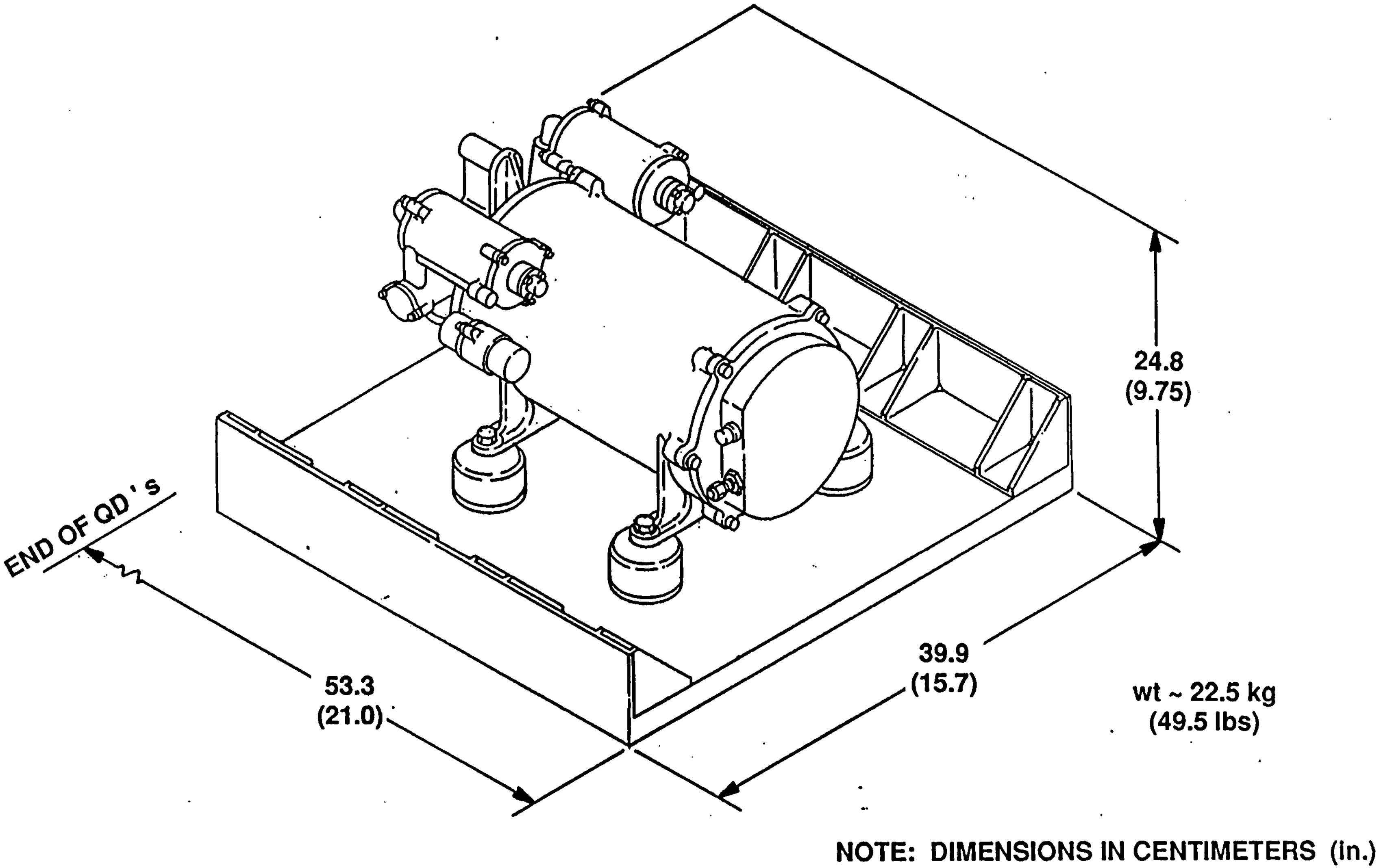
FIGURE 13



NOTE: DIMENSIONS IN CENTIMETERS (In.)

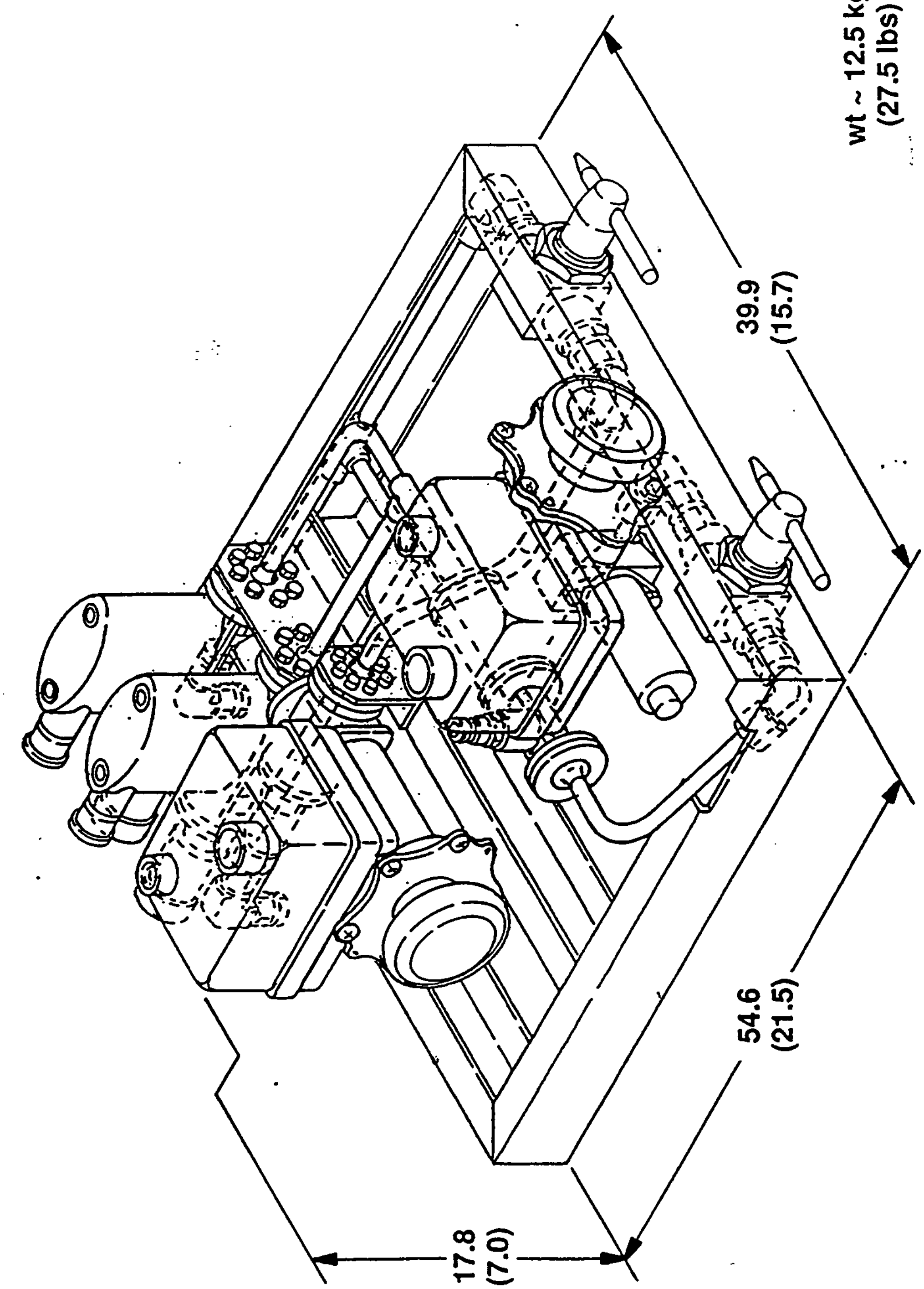
HEAT EXCHANGER

FIGURE 14



COOLANT PUMP ASSEMBLY

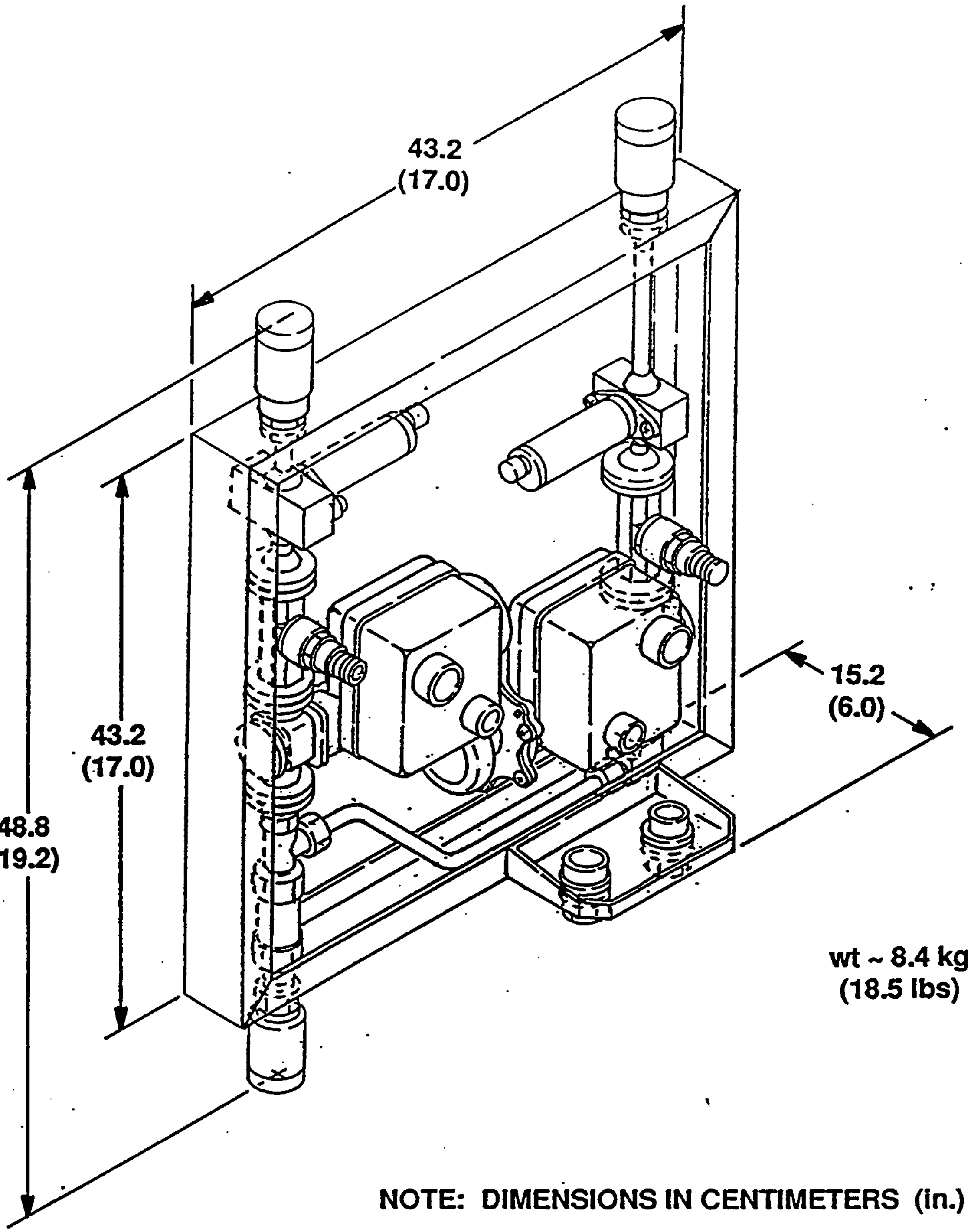
FIGURE 15



NOTE: DIMENSIONS IN CENTIMETERS (in.)

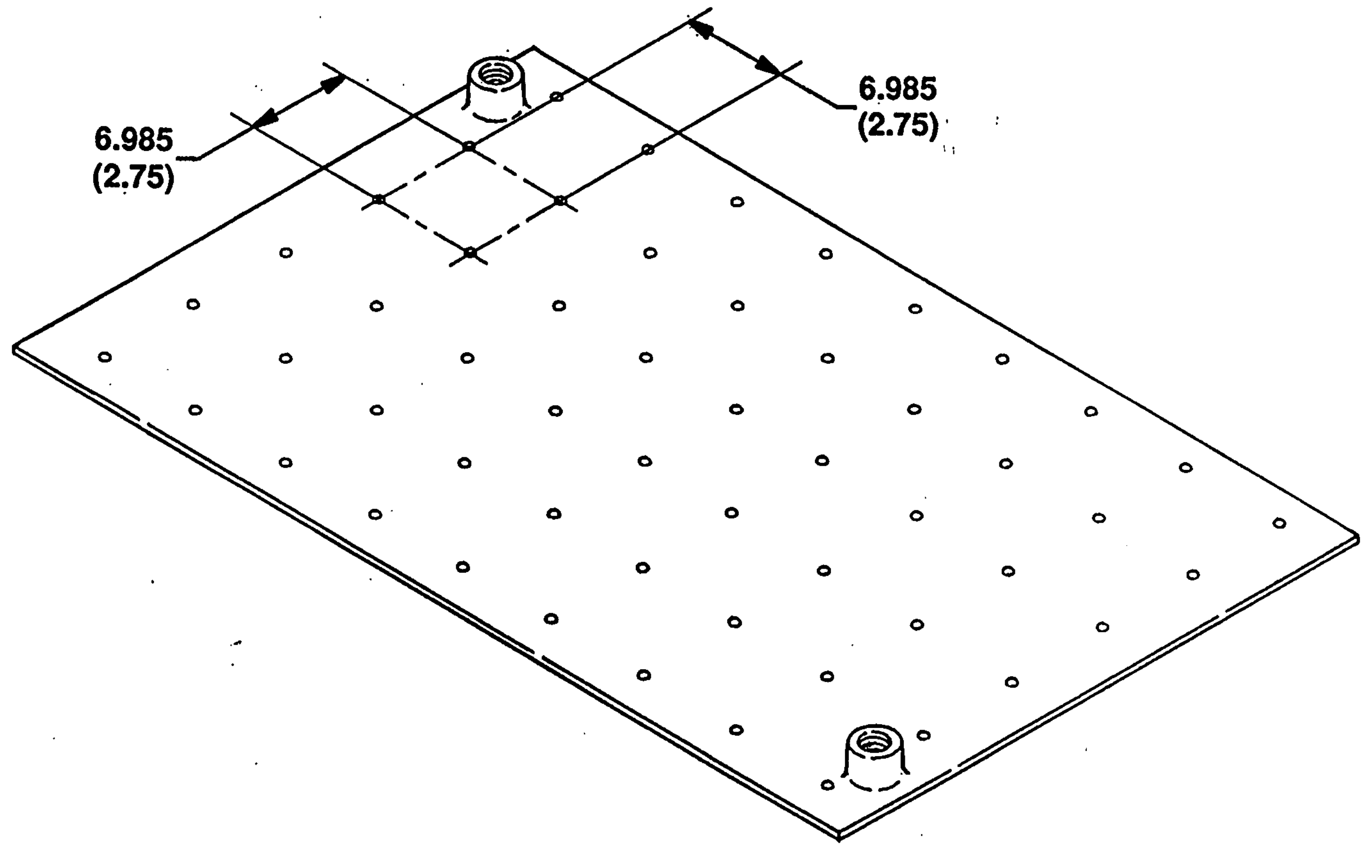
COOLANT CONTROL VALVE ASSEMBLY

FIGURE 16



COOLANT RETURN VALVE ASSEMBLY

FIGURE 17

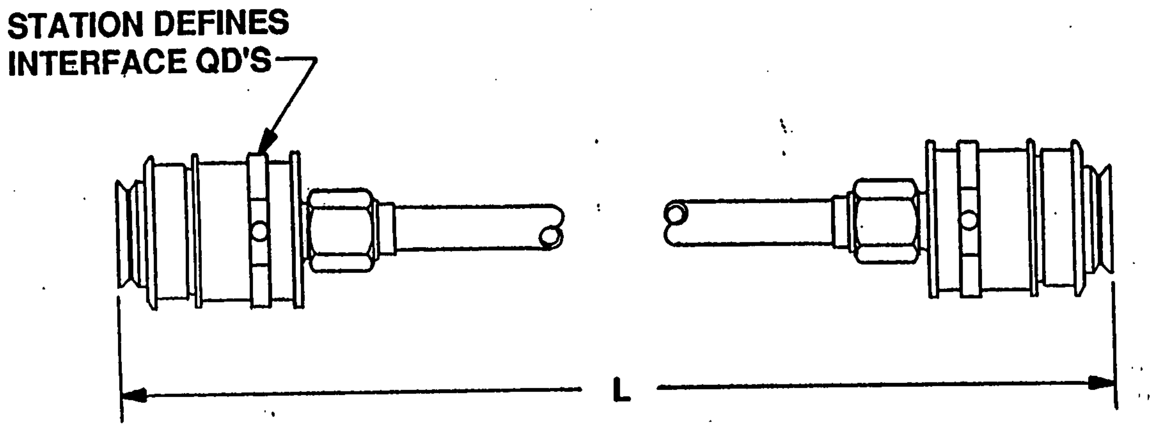


NOTE: DIMENSIONS IN CENTIMETERS (In.)

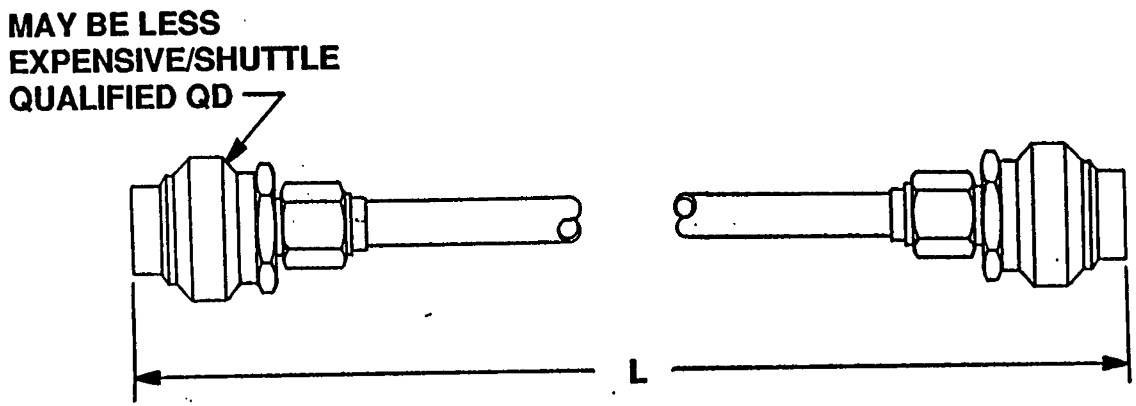
wt ~ TBD

COLD PLATE

FIGURE 18



STATION SUPPLY AND RETURN



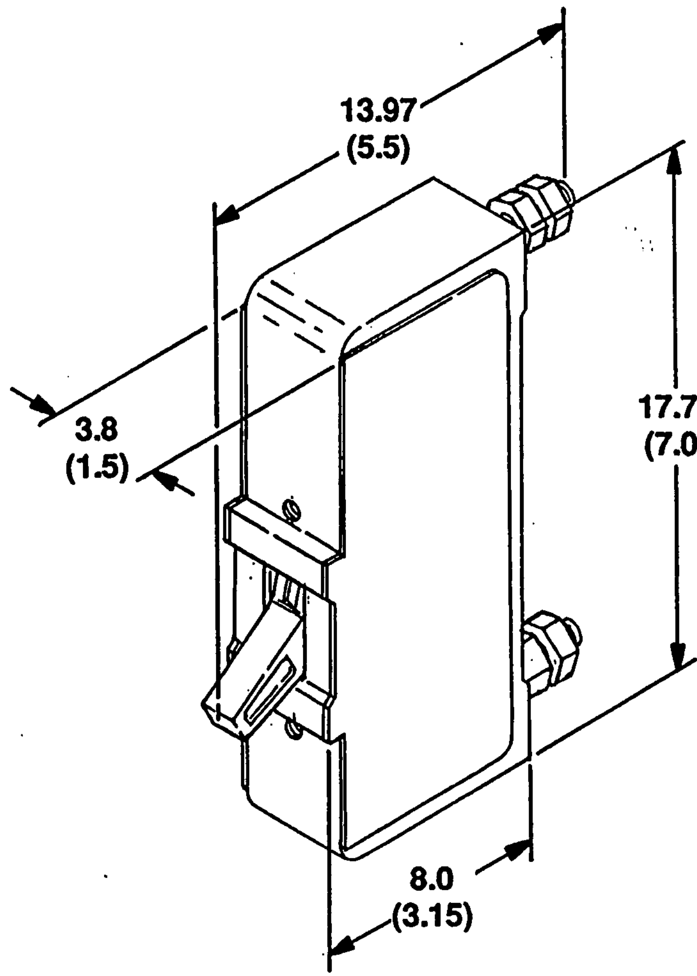
RACK INTERNAL HOSES

HOSE LIST

NAME	L (cm)
STATION SUPPLY	45.7
RETURN	81.0
RACK RETURN	96.0
COLDPLATE - 1	63.5
- 2	35.5
- 3	73.5
- 4	96.0
- 5	35.5
- 6	63.5
- 7	56.0

TCS HOSE ASSEMBLIES

FIGURE 19

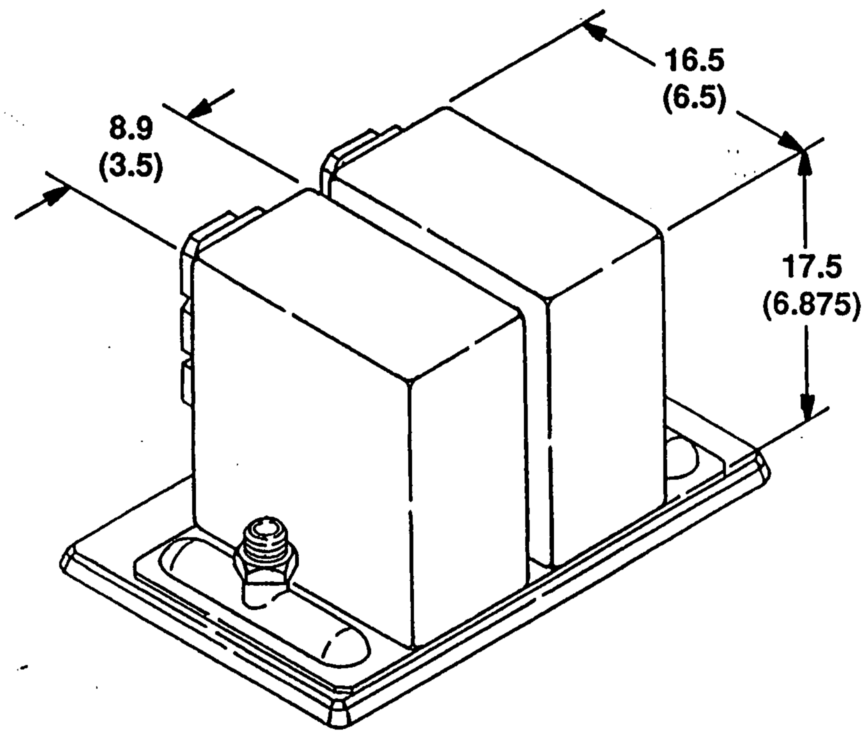


wt ~ 1.0 kg
(2.2 lbs)

NOTE: DIMENSIONS IN CENTIMETERS (In.)

MANUAL CIRCUIT BREAKER

FIGURE 20

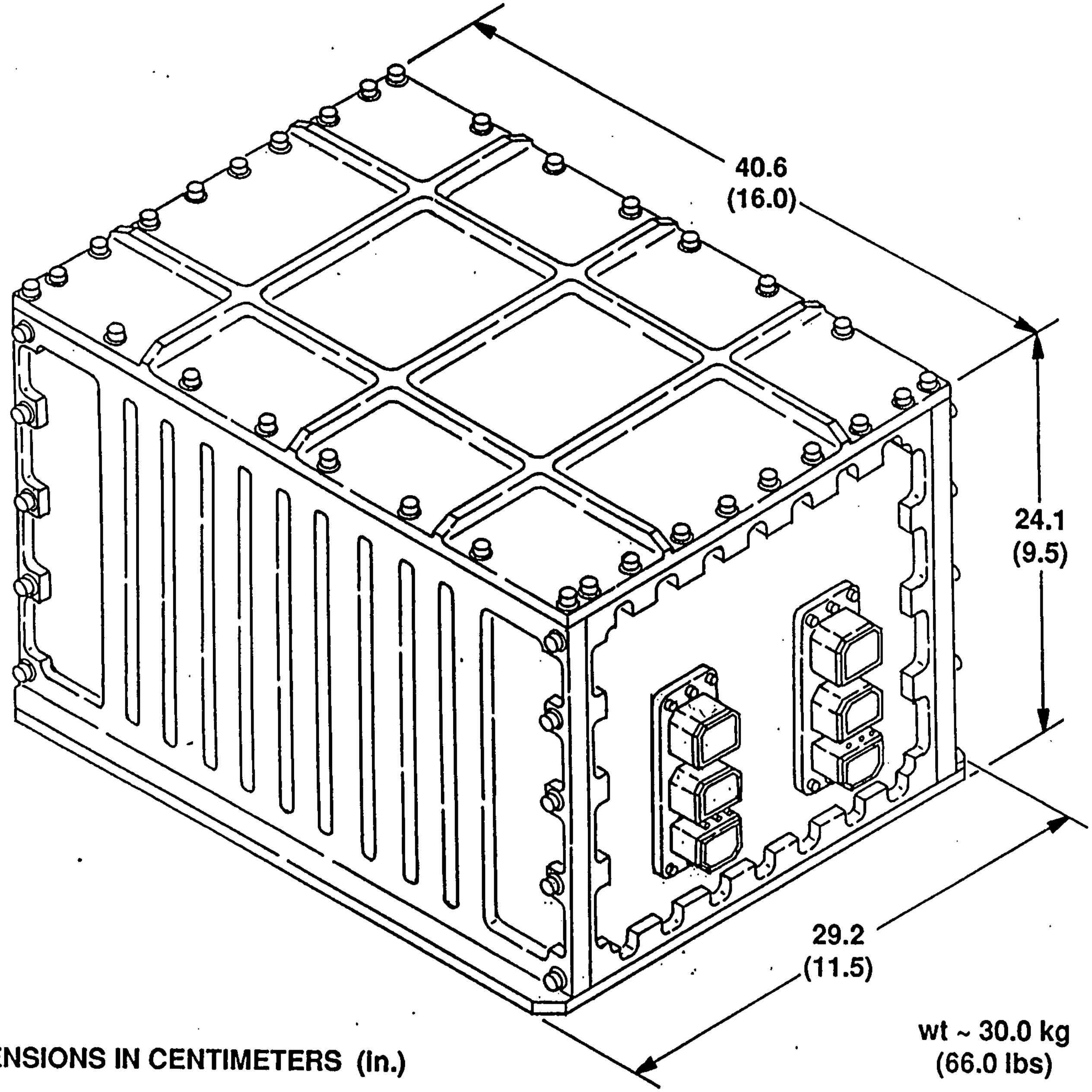


wt ~ 6 kg
(13.2 lbs)

NOTE: DIMENSIONS IN CENTIMETERS (In.)

REMOTE POWER CONTROL MODULE (RPCM)

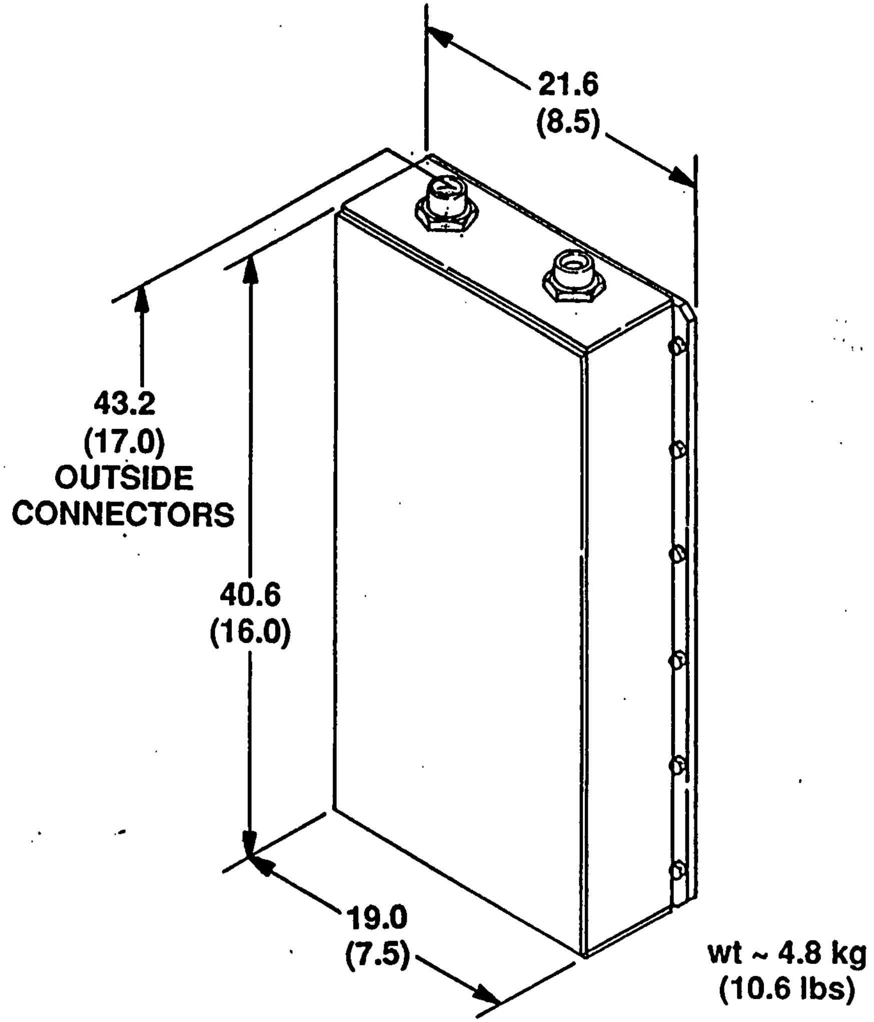
FIGURE 21



NOTE: DIMENSIONS IN CENTIMETERS (In.)

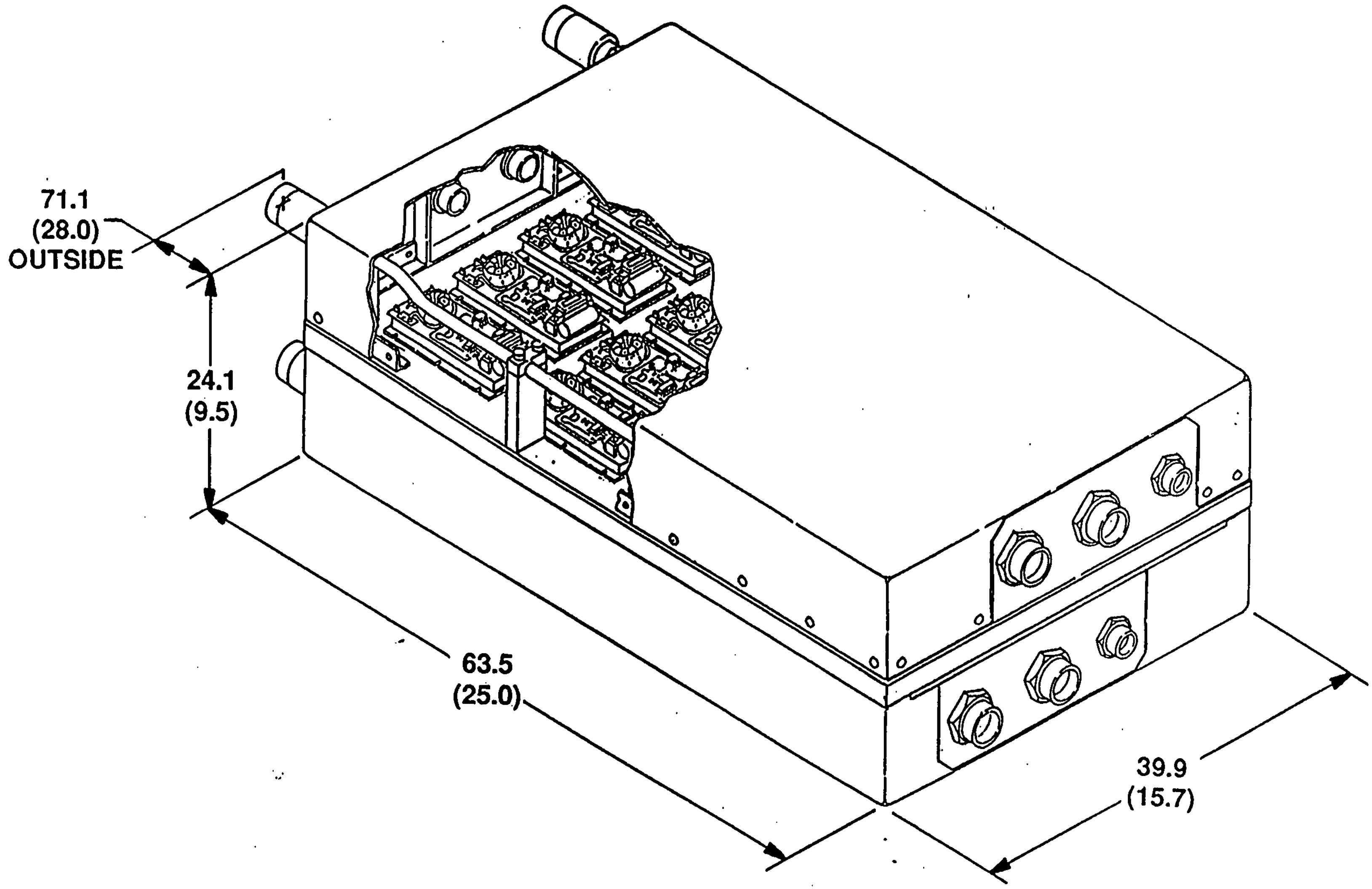
PRIMARY DISTRIBUTION BOX

FIGURE 22



ESSENTIAL POWER SUPPLY

FIGURE 23

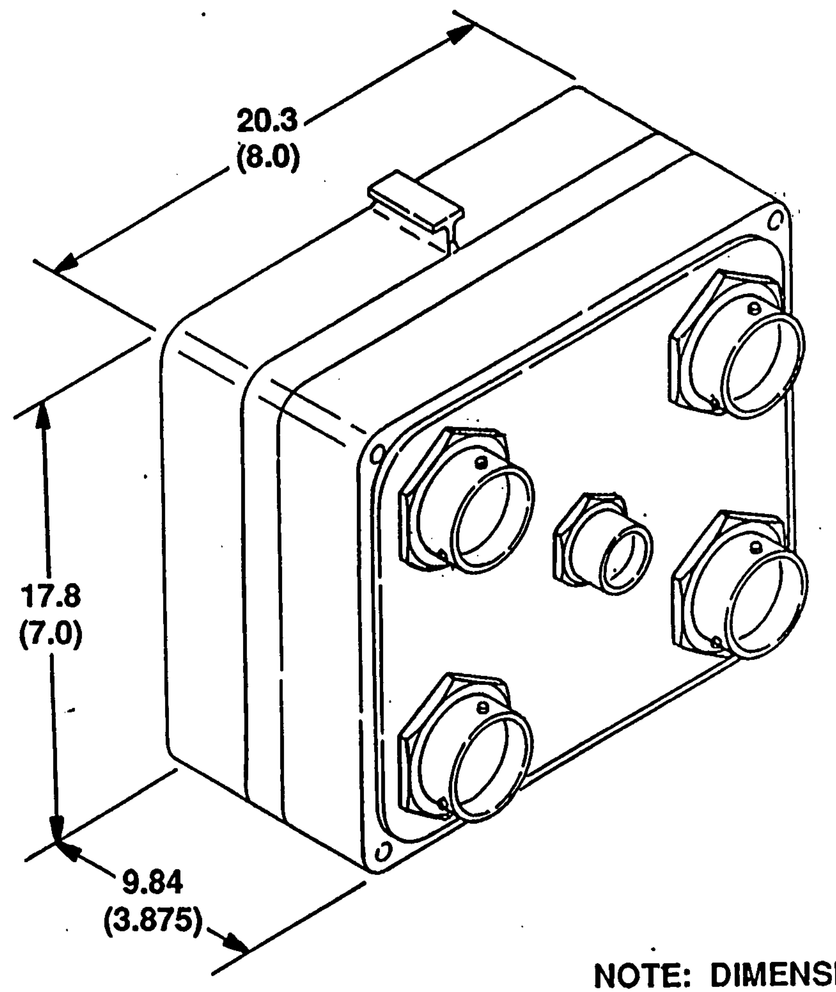


NOTE: DIMENSIONS IN CENTIMETERS (In.)

wt ~ 23.6 kg
(52.0 lbs)

CORE POWER CONDITIONER
(SHOWN CUT AWAY)

FIGURE 24

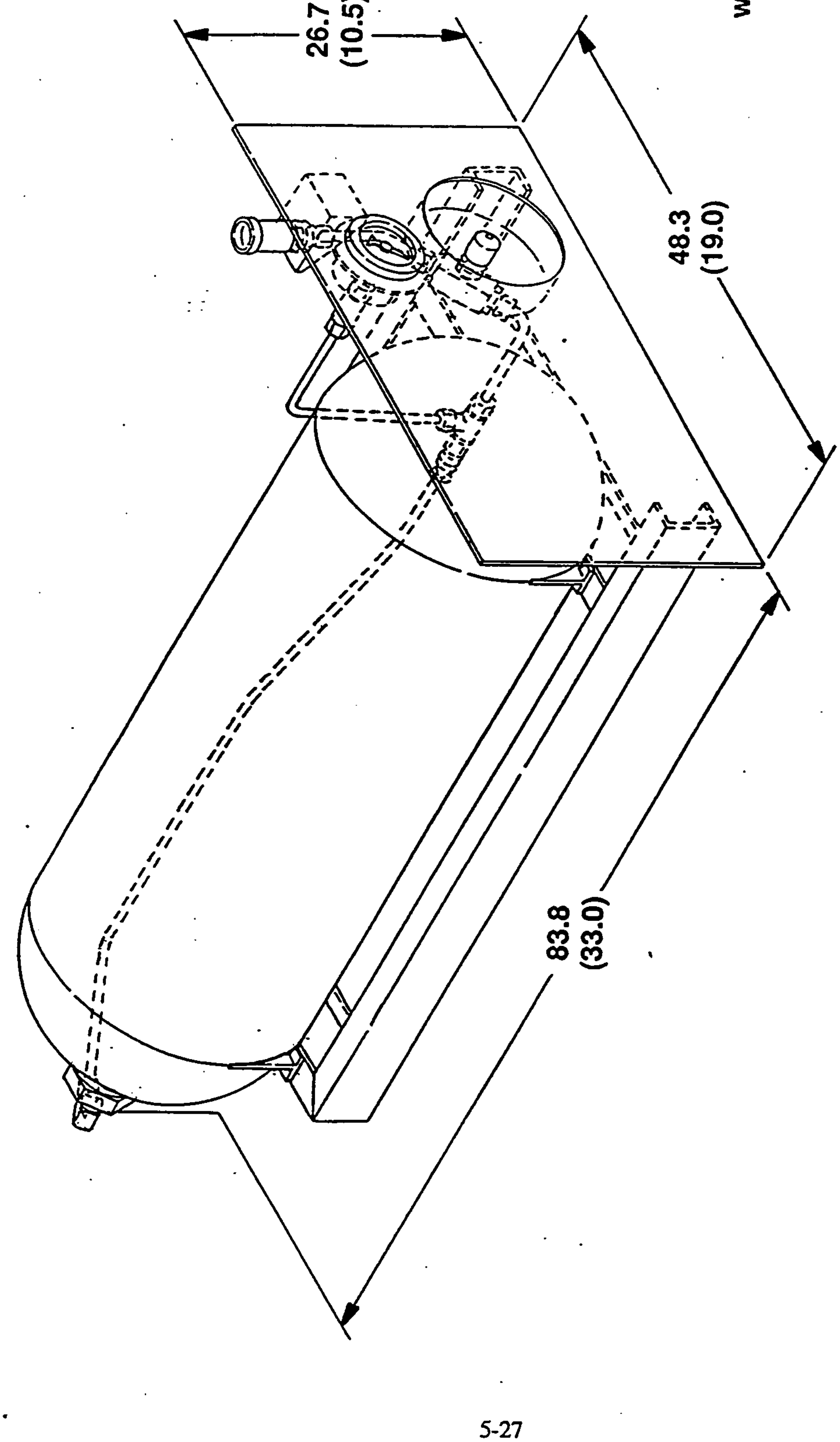


wt ~ 4.5 kg
(9.9 lbs)

NOTE: DIMENSIONS IN CENTIMETERS (in.)

CORE JUNCTION BOX

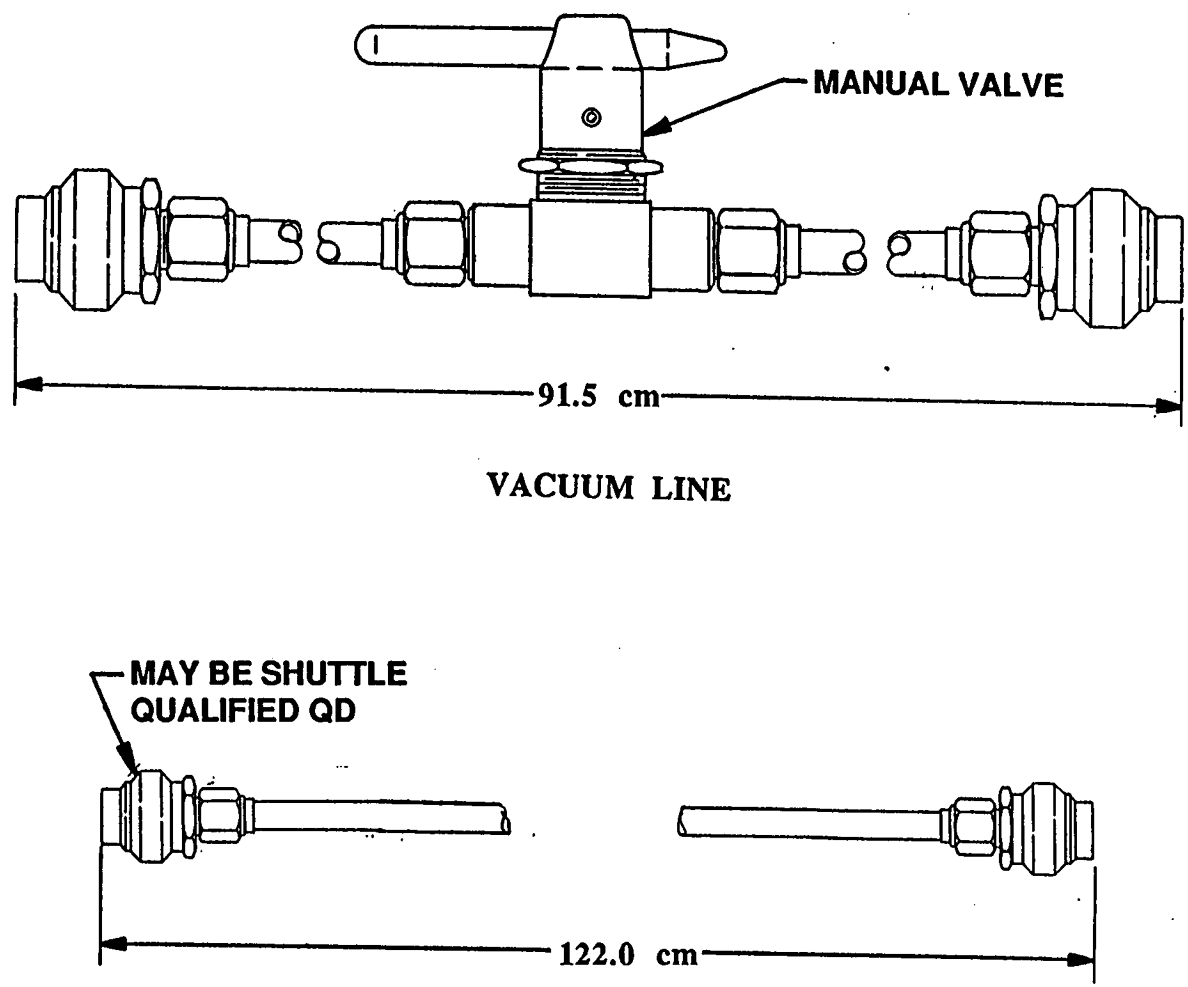
FIGURE 25



NOTE: DIMENSIONS IN CENTIMETERS (In.)

GAS SUPPLY MODULE

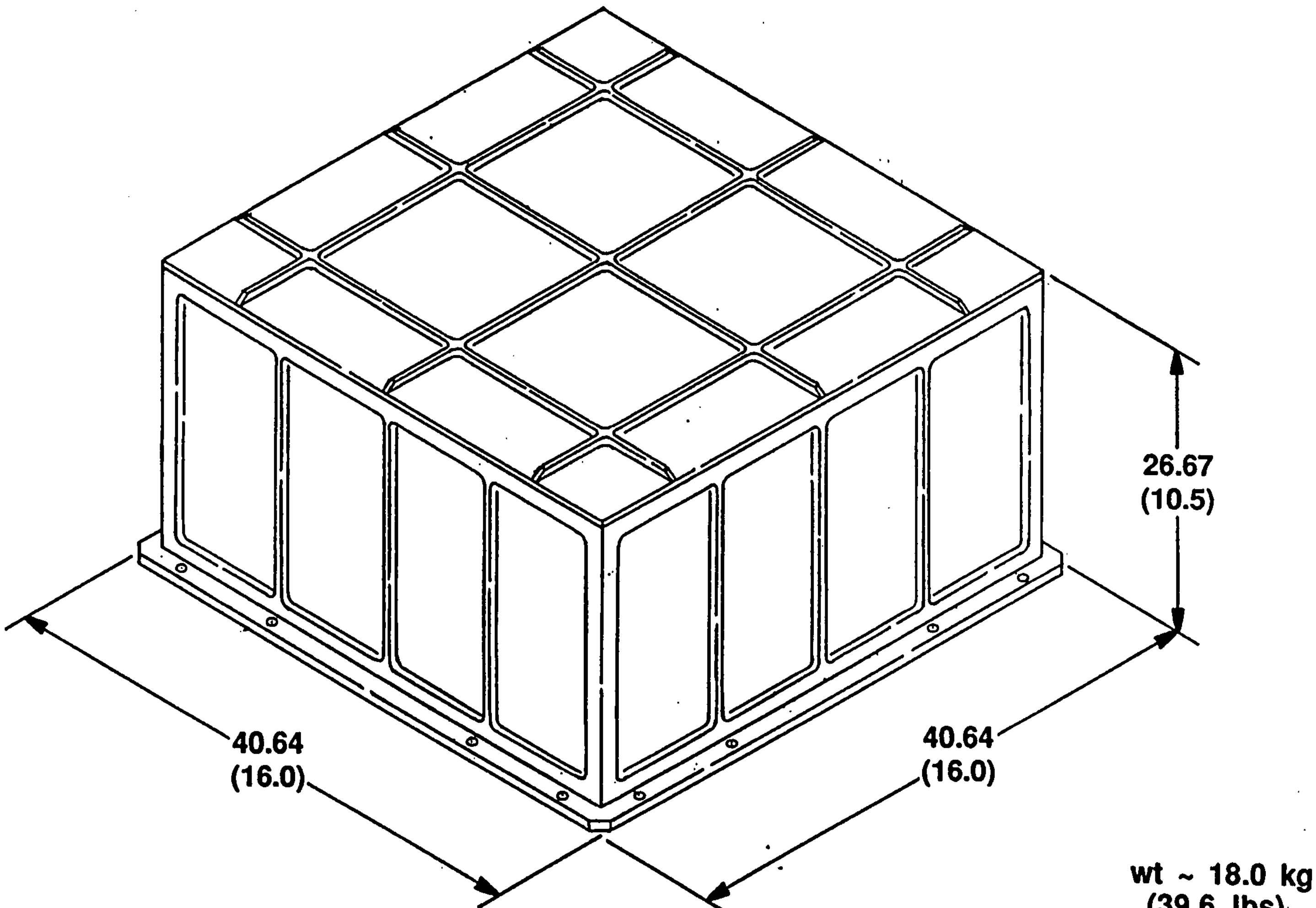
FIGURE 26



GAS SUPPLY

GDS HOSE ASSEMBLIES

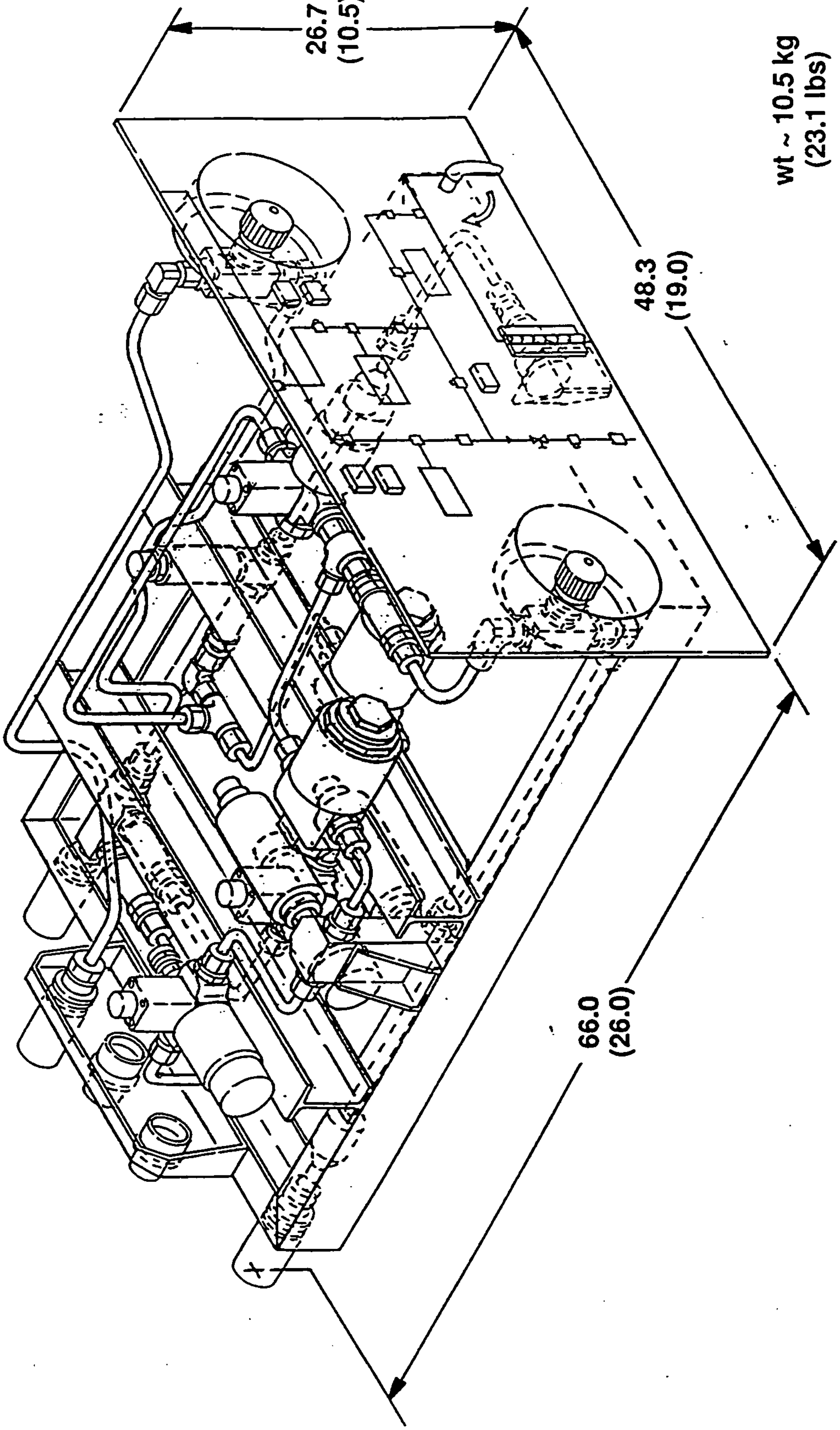
FIGURE 27



NOTE: DIMENSIONS IN CENTIMETERS (in.)

CONTAMINATION ELECTRONICS

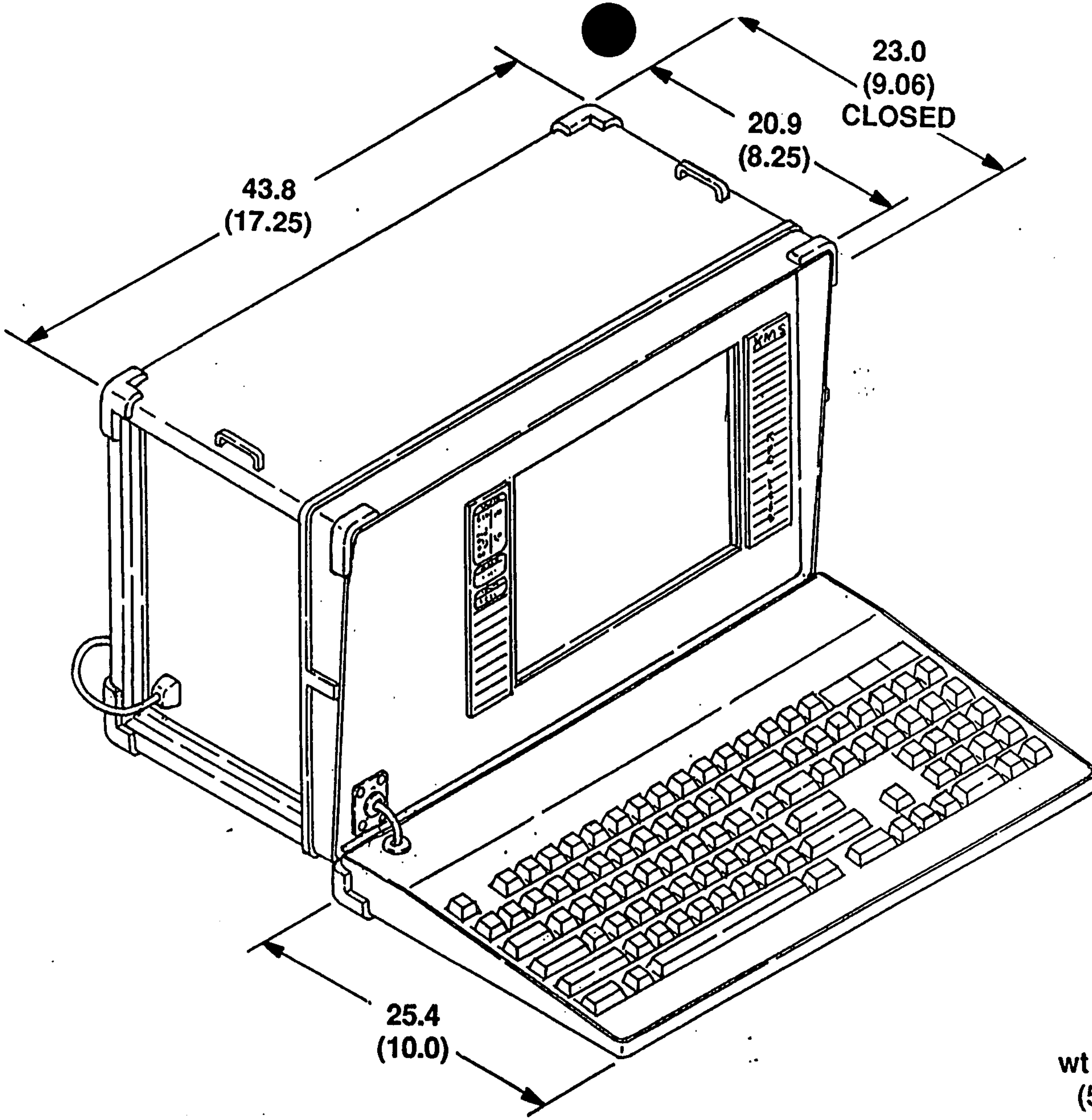
FIGURE 28



NOTE: DIMENSIONS IN CENTIMETERS (In.)

GAS CONTROL ASSEMBLY

FIGURE 29

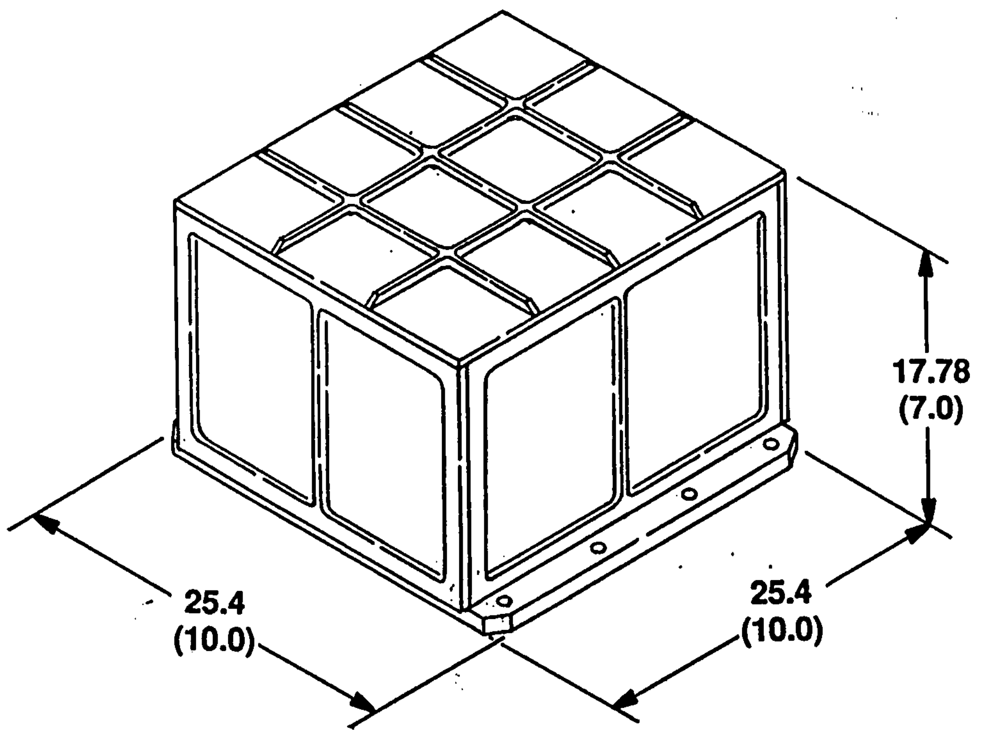


wt ~ 23.0 kg
(50.6 lbs)

NOTE: DIMENSIONS IN CENTIMETERS (in.)

CREW INTERFACE
KEYBOARD AND MONITOR

FIGURE 30

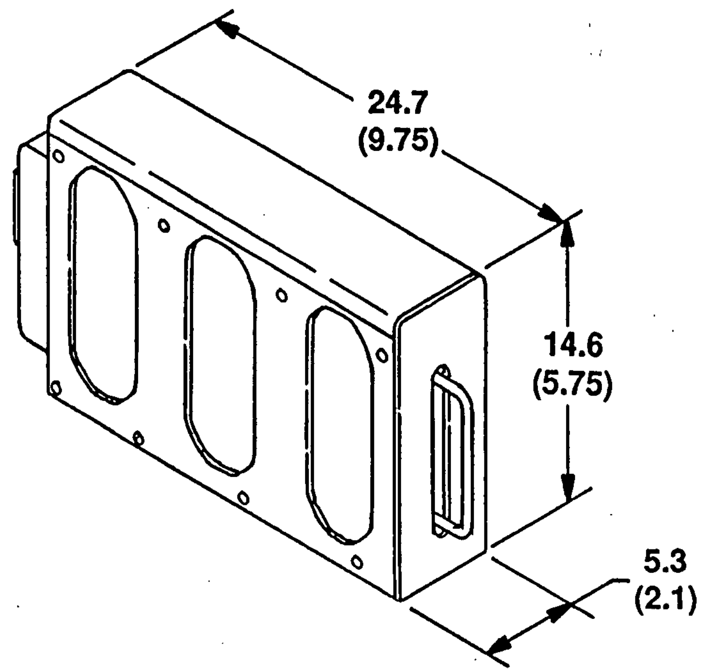


wt ~ 7.7 kg
(16.9 lbs)

NOTE: DIMENSIONS IN CENTIMETERS (In.)

CD ROM

FIGURE 31

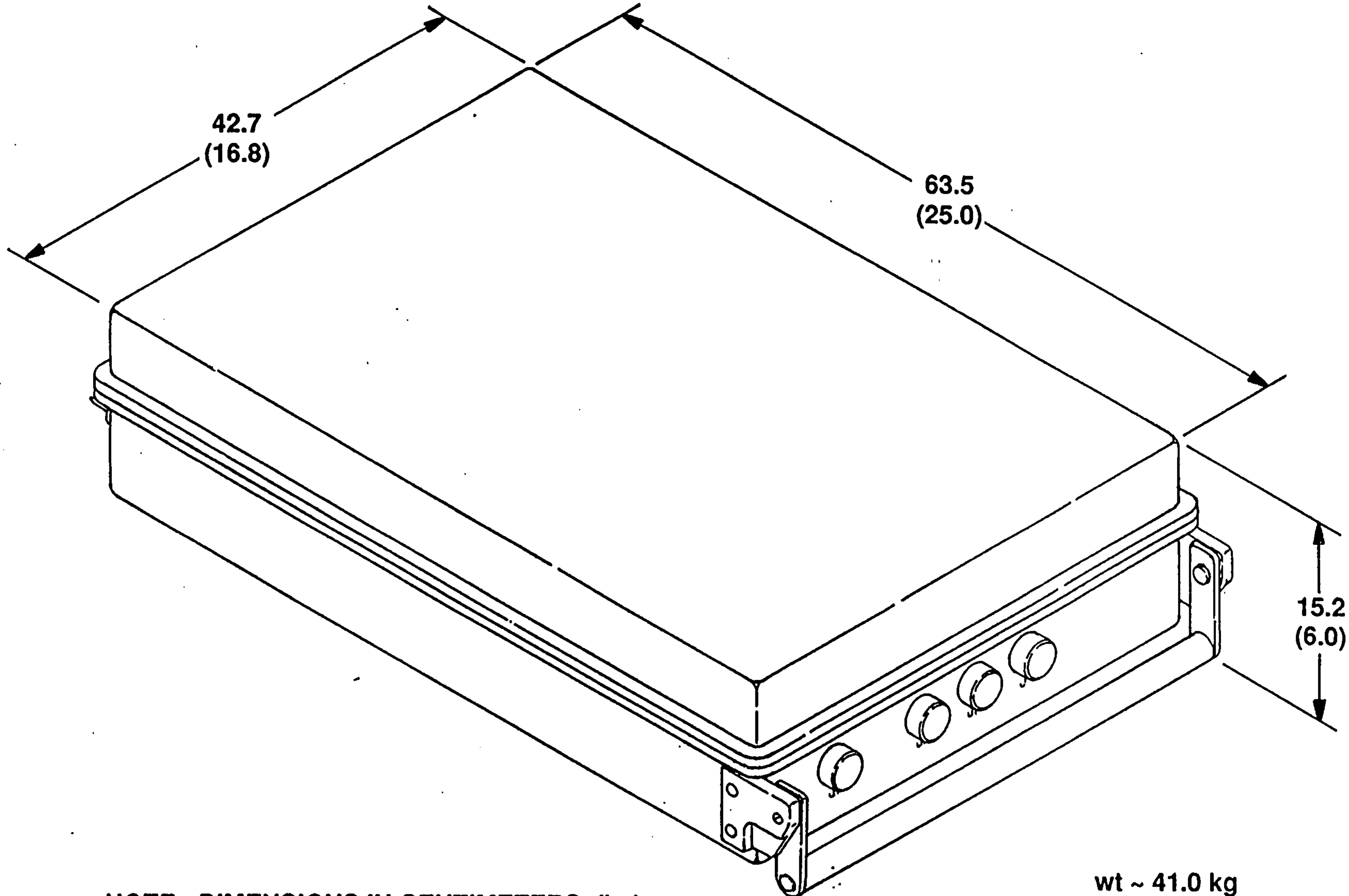


NOTE: DIMENSIONS IN CENTIMETERS (in.)

wt ~ 2.0 kg
(4.4 lbs)

REMOVABLE HARD DRIVE

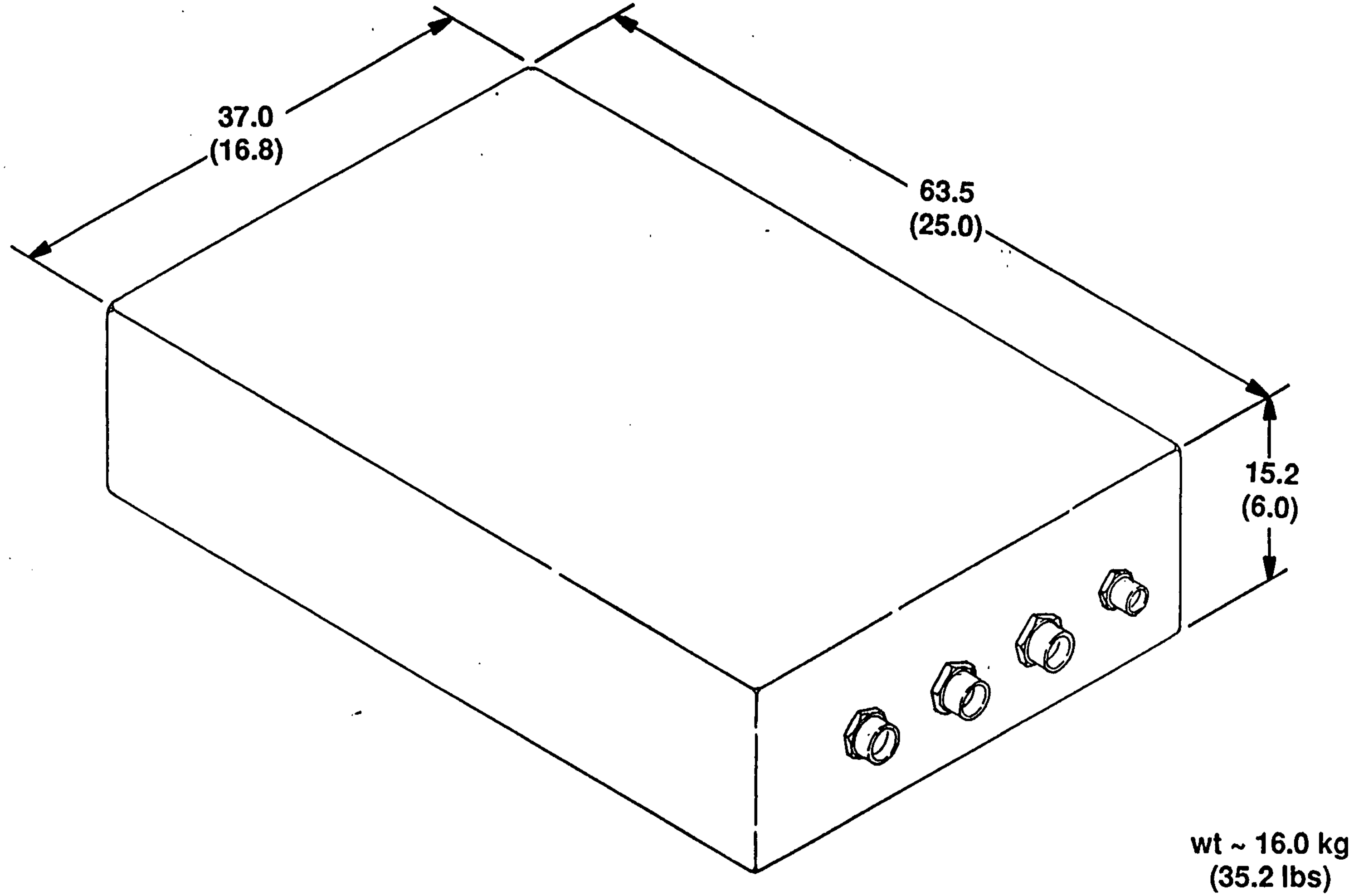
FIGURE 32



NOTE: DIMENSIONS IN CENTIMETERS (In.)

HIGH DENSITY TAPE RECORDER

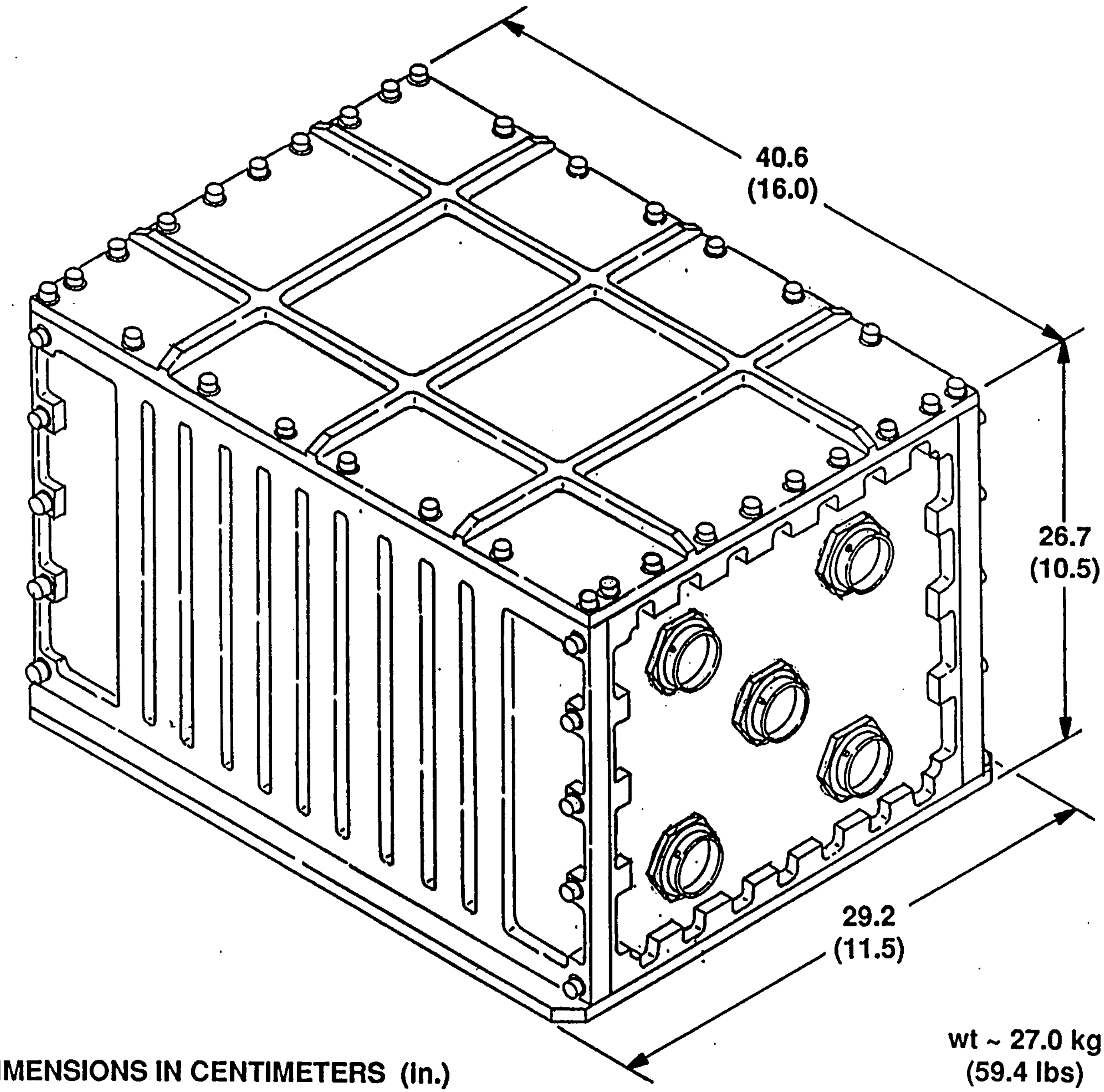
FIGURE 33



NOTE: DIMENSIONS IN CENTIMETERS (In.)

TAPE RECORDER ELECTRONICS

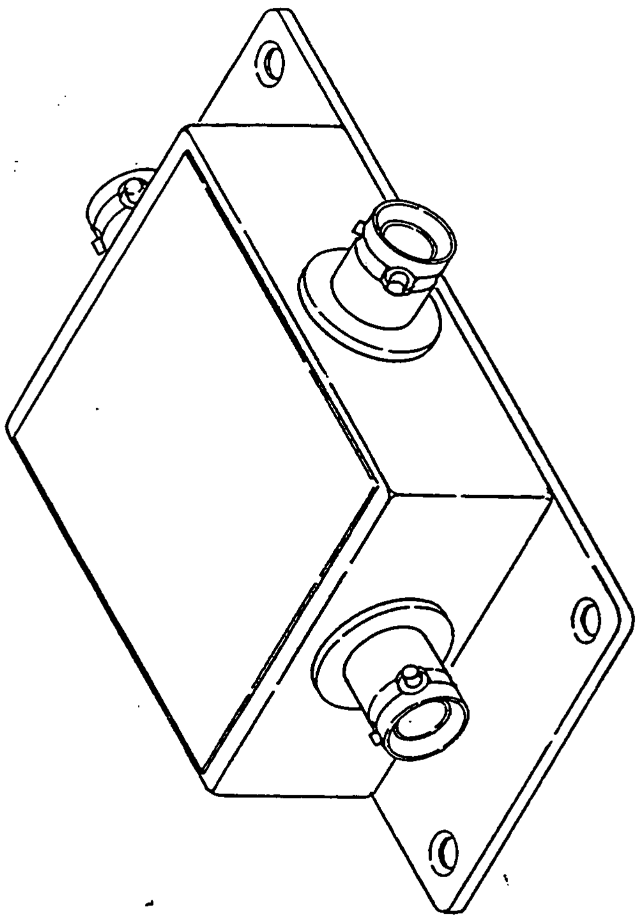
FIGURE 34



NOTE: DIMENSIONS IN CENTIMETERS (In.)

VIDEO PROCESSOR

FIGURE 35



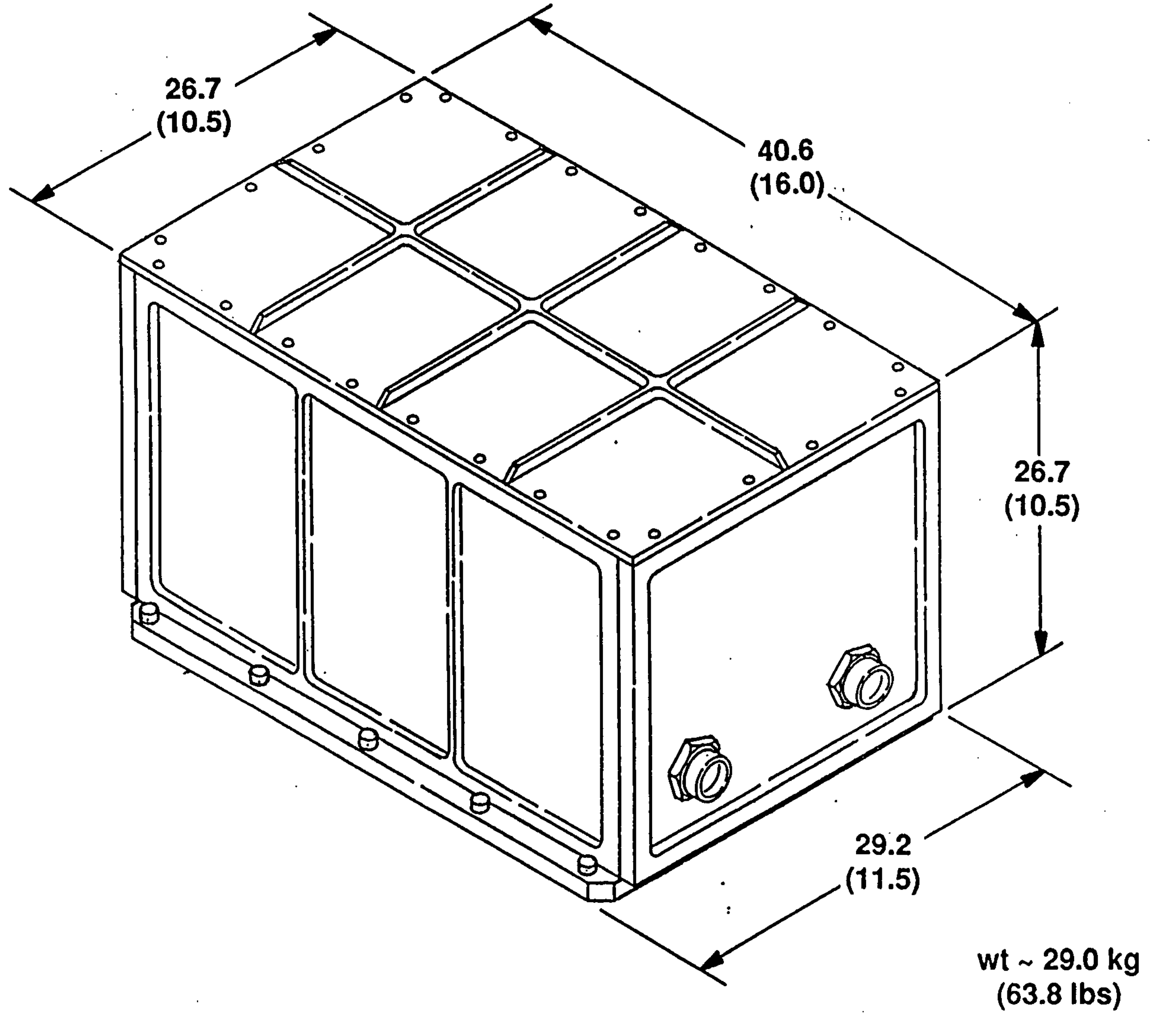
BUS COUPLER

FIGURE 36

TO BE DETERMINED

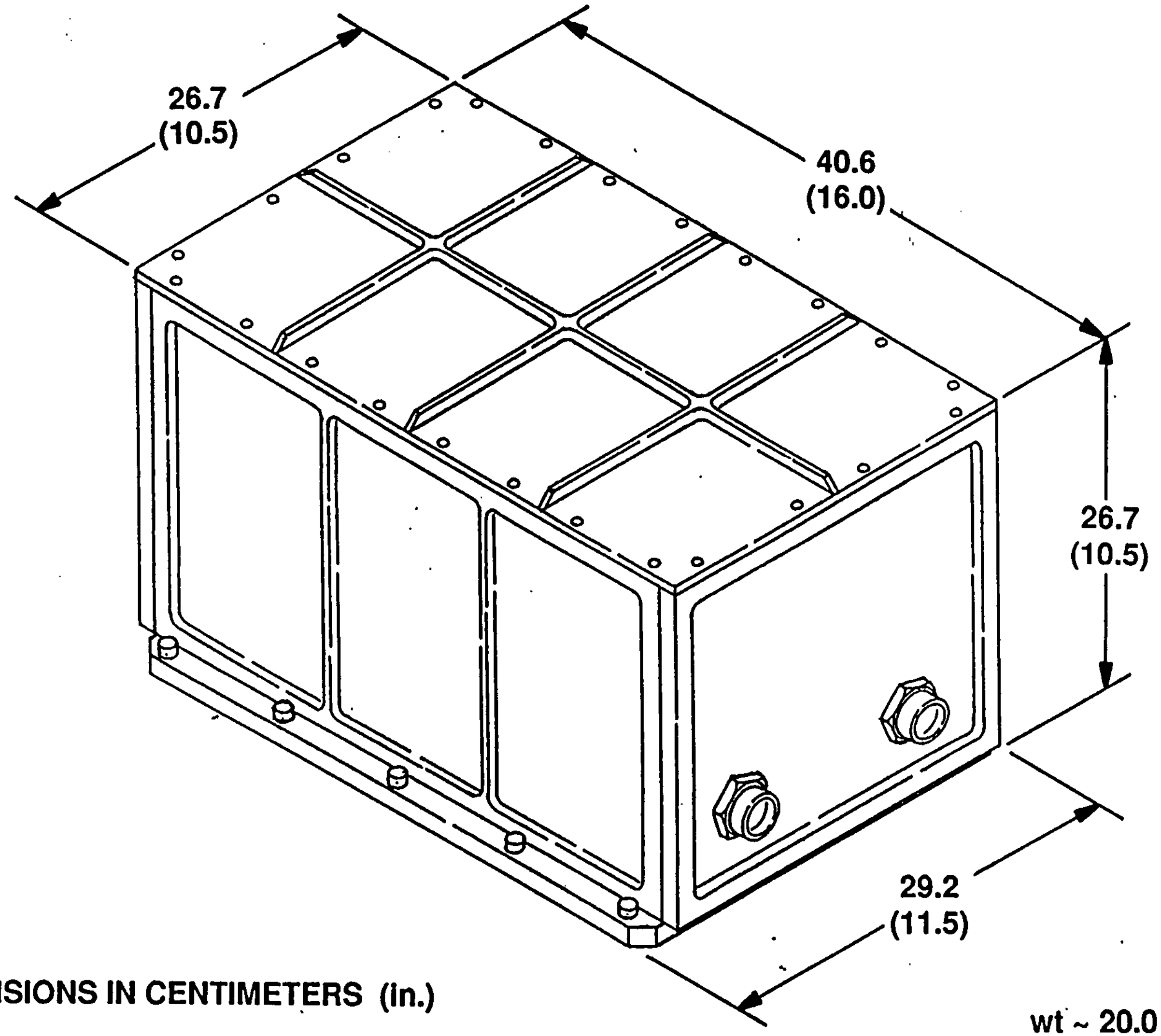
DMS CABLE ASSEMBLIES

FIGURE 37



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 38 CORE CONTROL UNIT

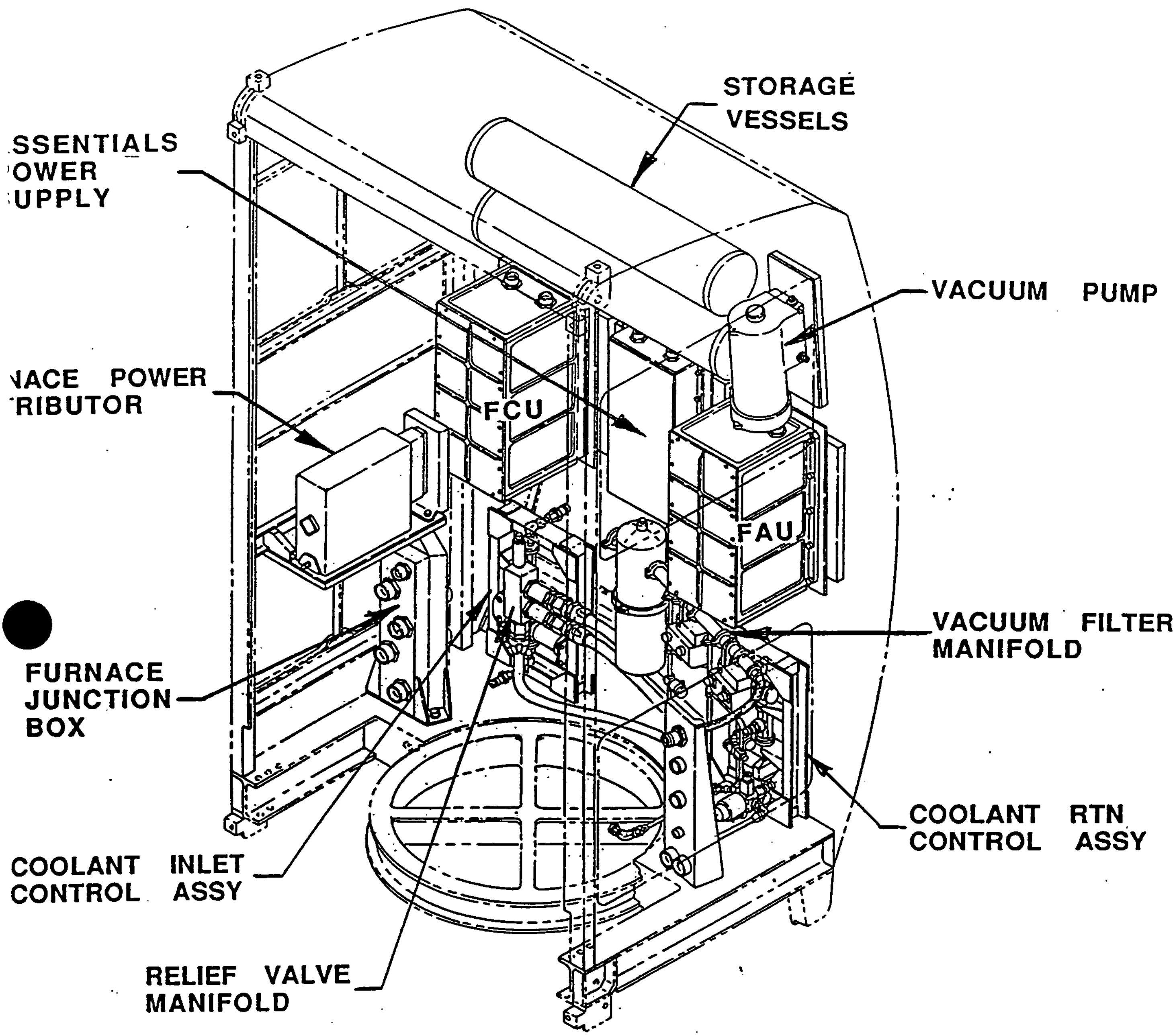


NOTE: DIMENSIONS IN CENTIMETERS (in.)

wt ~ 20.0 kg
(44.0 lbs)

CORE MONITOR/CONTROL UNIT

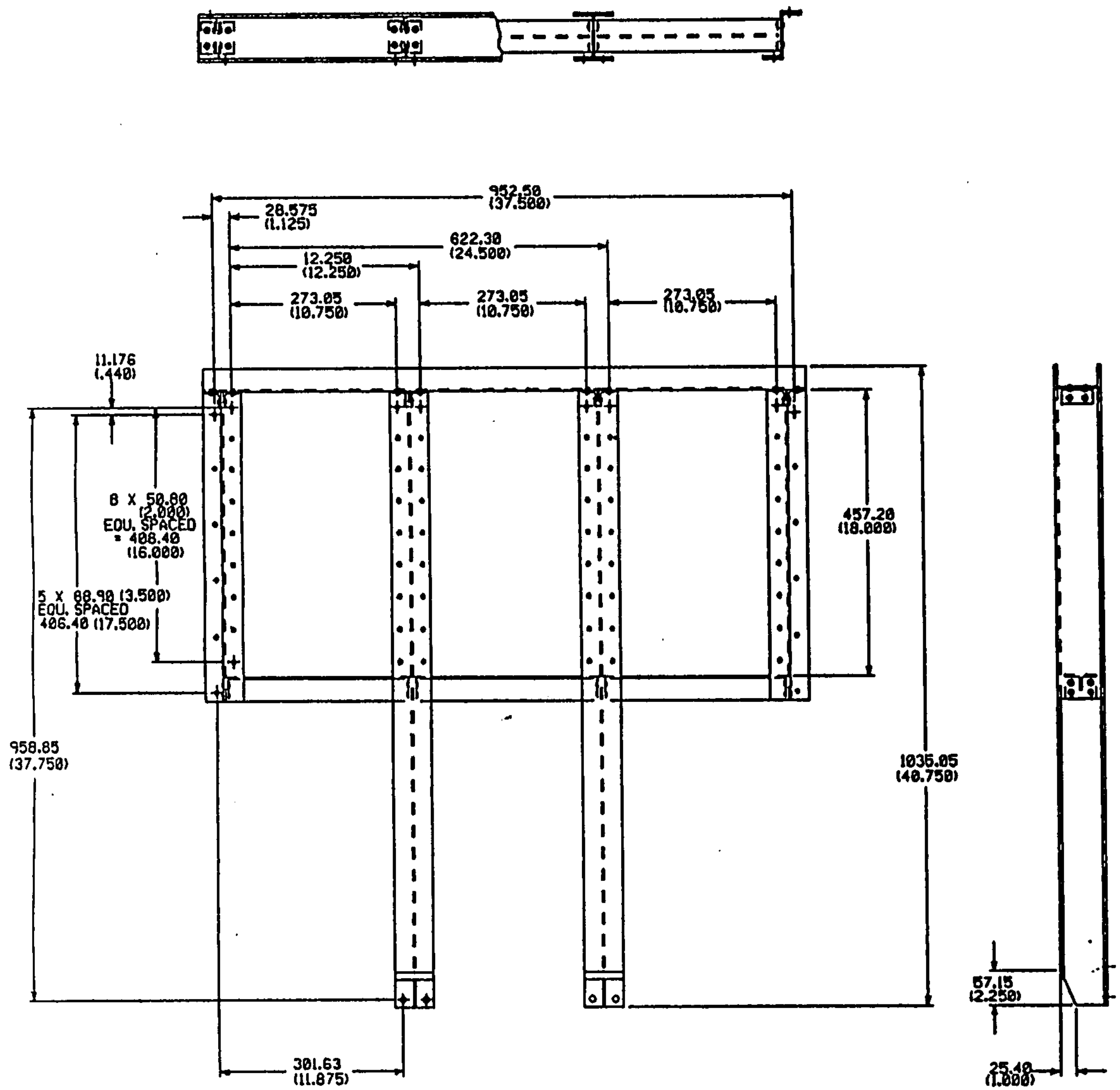
FIGURE 39

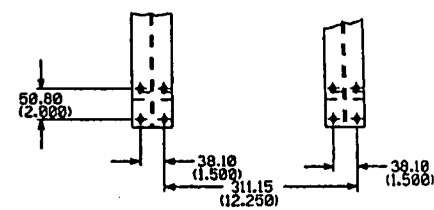


FURNACE RACK

SUBSYSTEM ARRANGEMENT

FIGURE 40



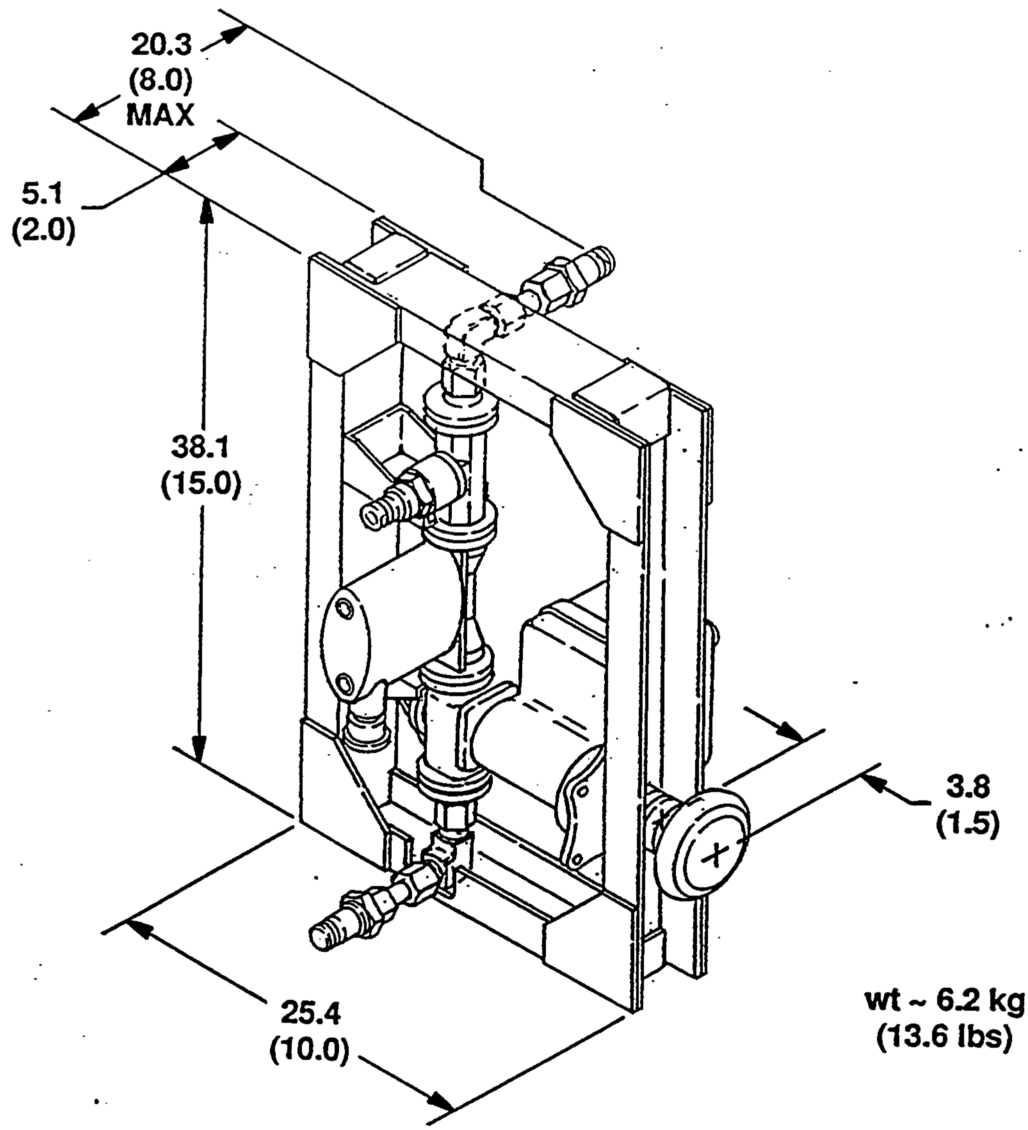


NOTES:

1. REMOVE BURRS AND BREAK SHARP EDGES.
2. ALL MACHINED SURFACES 125/ UNLESS OTHERWISE STATED.
3. MATERIAL: 6061-T6 ALUMINUM ALLOY CHANNEL, 3.0 X .13 WEB WITH 1.5 WIDE FLANGE PER QQ-A-200/16.
4. MATERIAL: 6061-T6 ALUMINUM ALLOY TEE, 3.0 X .13 WEB WITH 2.5 WIDE FLANGE PER QQ-A-200/16.
5. FINISH: CHEMICAL FILM PER MIL-C-5541, CLASS 3.

EQUIPMENT SUPPORT FRAME

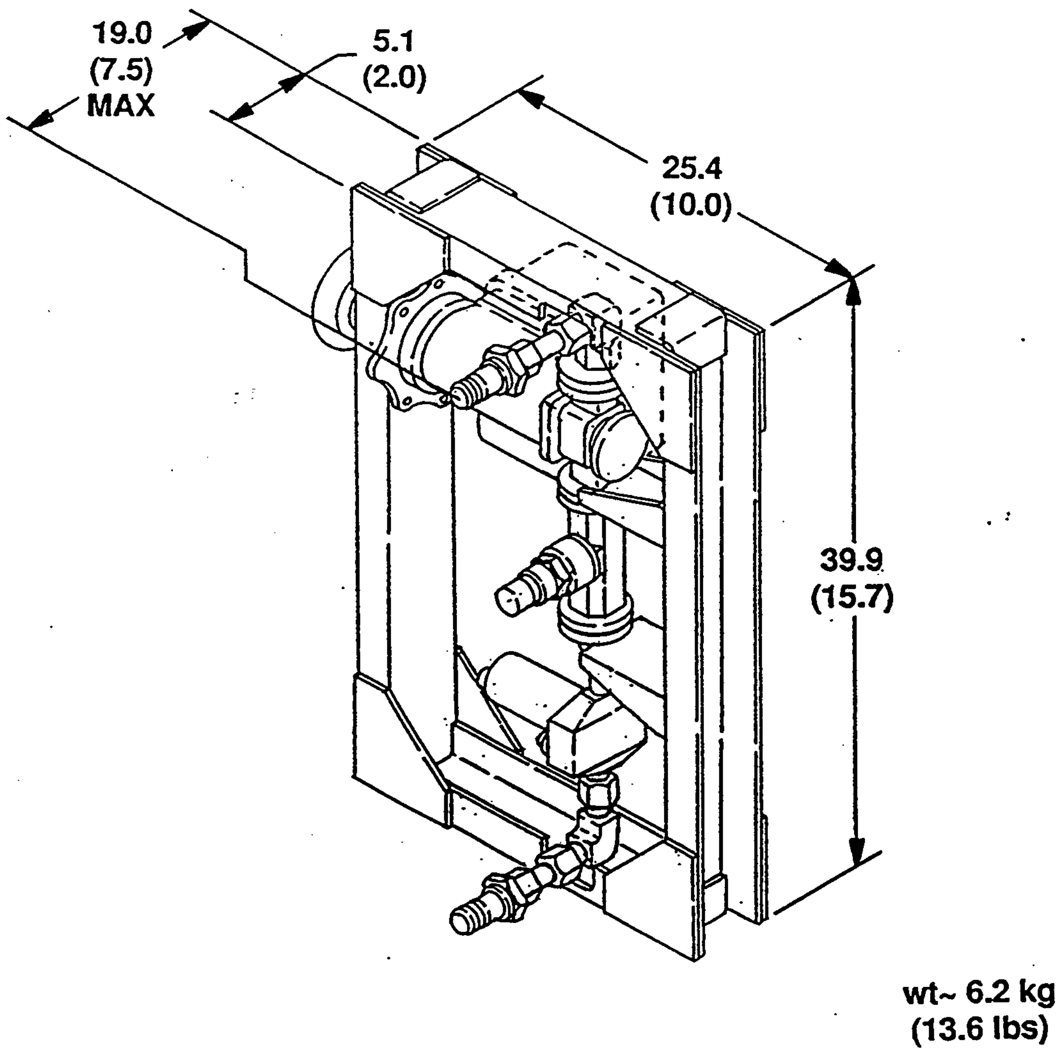
FIGURE 41



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FURNACE COOLANT INLET
CONTROL ASSEMBLY

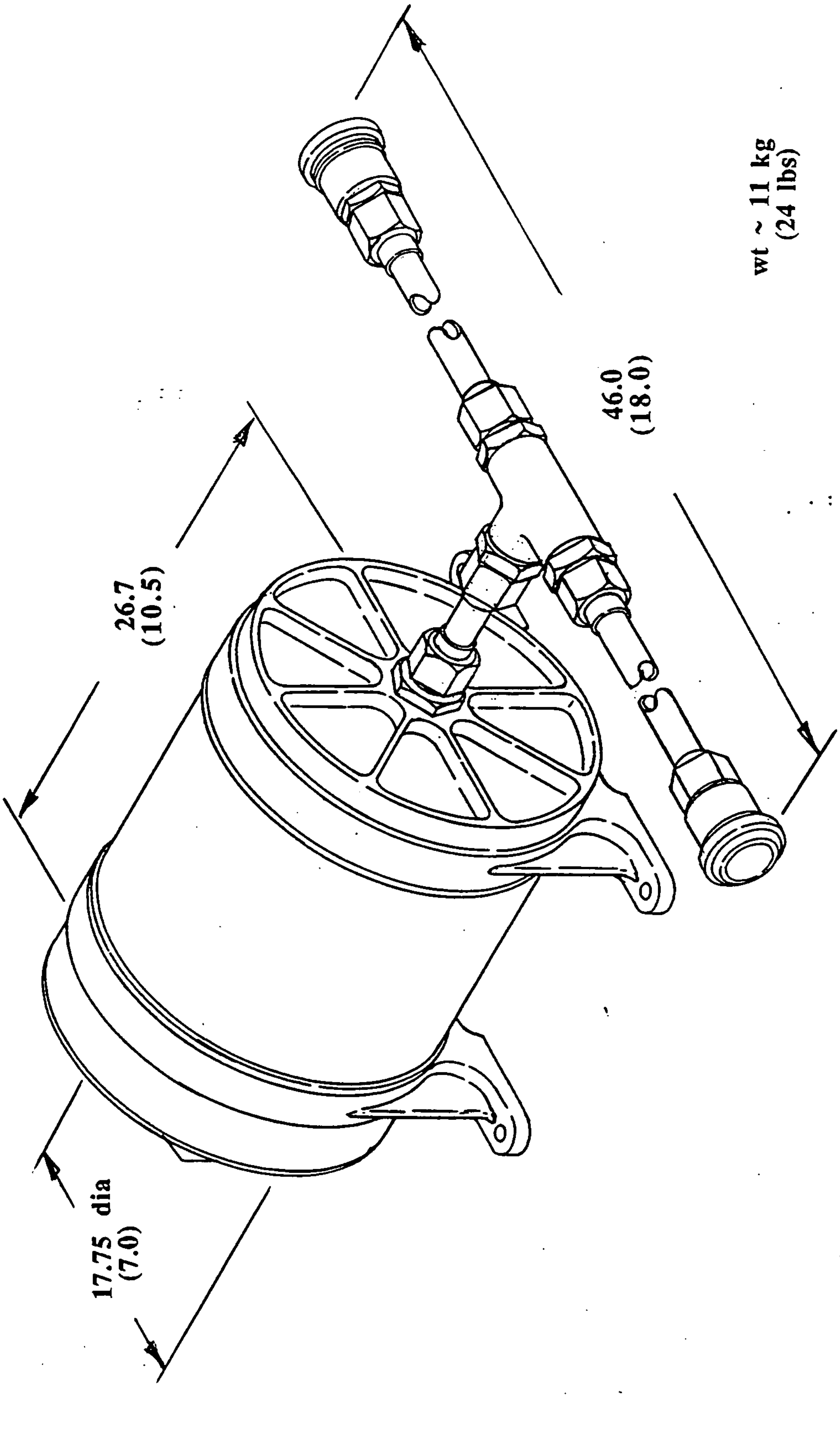
FIGURE 42



NOTE: DIMENSIONS IN CENTIMETERS (in.)

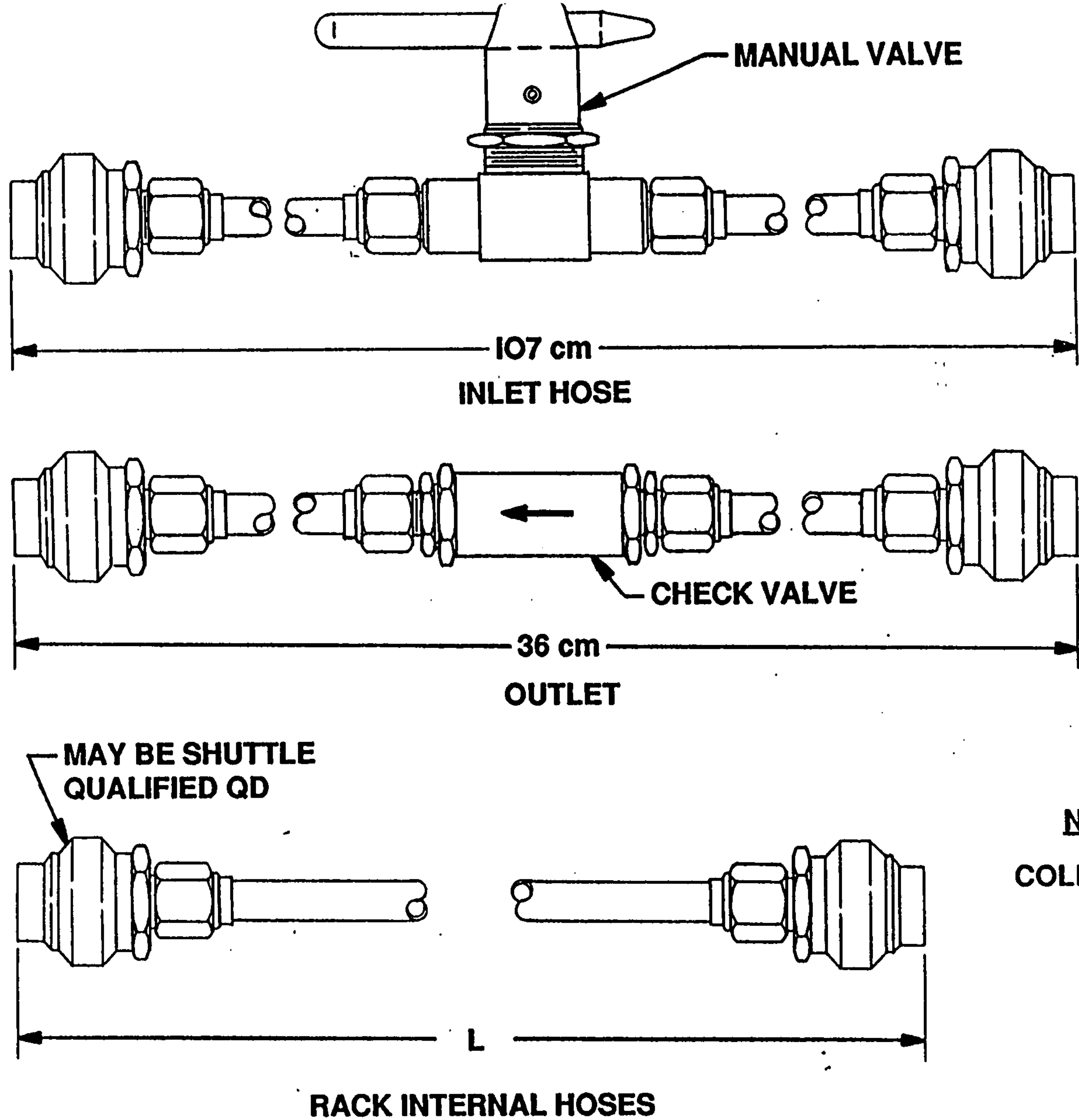
FURNACE COOLANT RETURN
CONTROL ASSEMBLY

FIGURE 43



TCS ACCUMULATOR ASSEMBLY

FIGURE 44

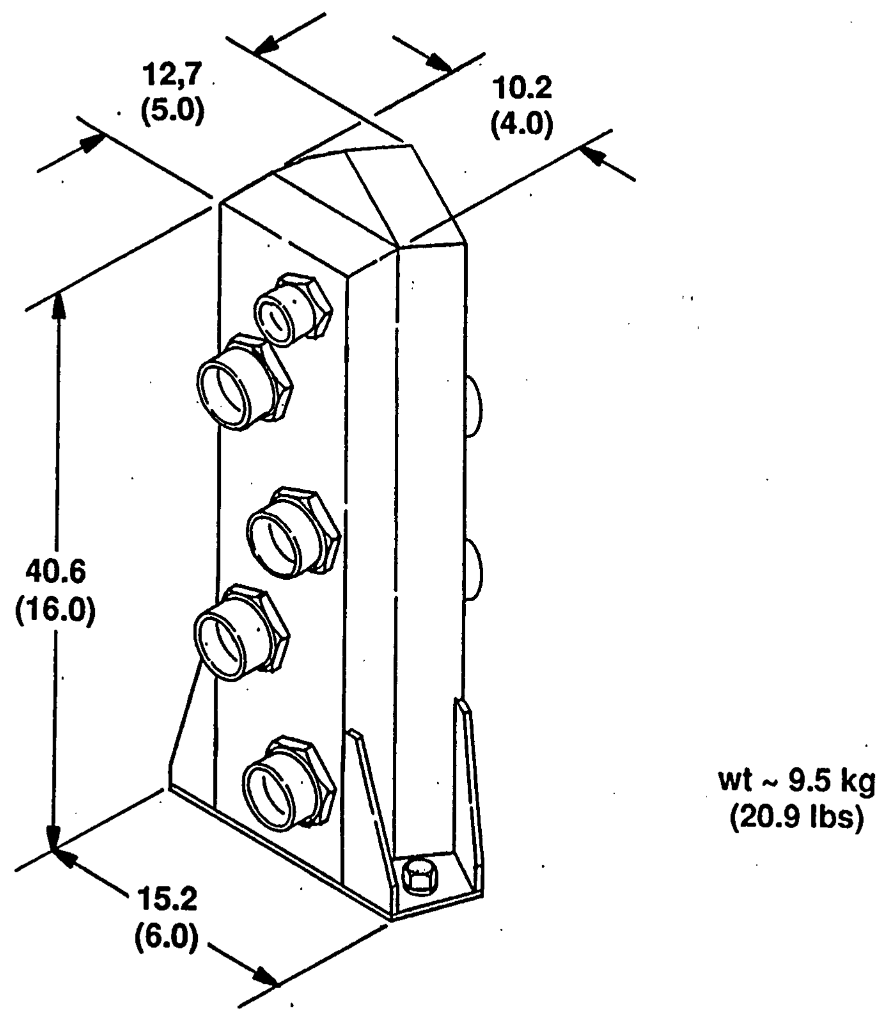


HOSE LIST

NAME	L (cm)
COLDPLATE - 1	25.4
- 2	40.0
- 3	40.0
- 4	36.0
- 5	90.0

EXPERIMENT RACK HOSE ASSEMBLIES

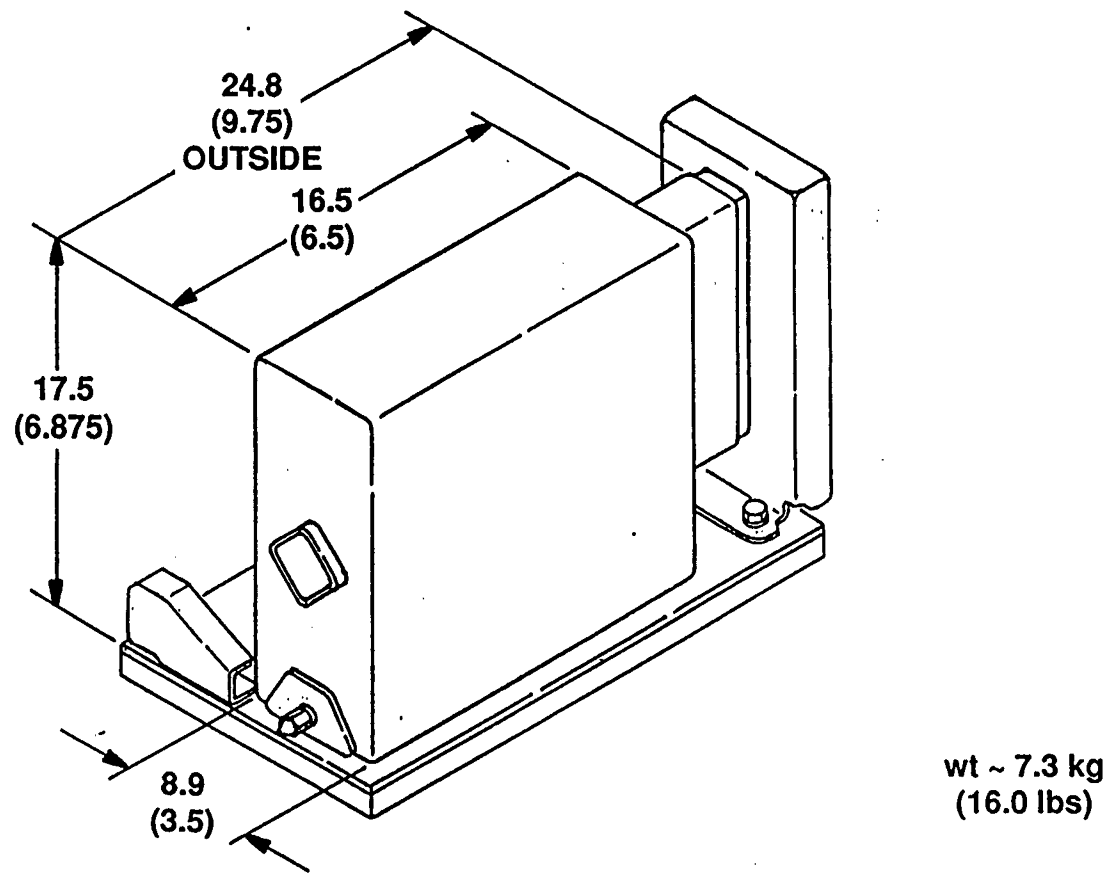
FIGURE 45



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FURNACE JUNCTION BOX

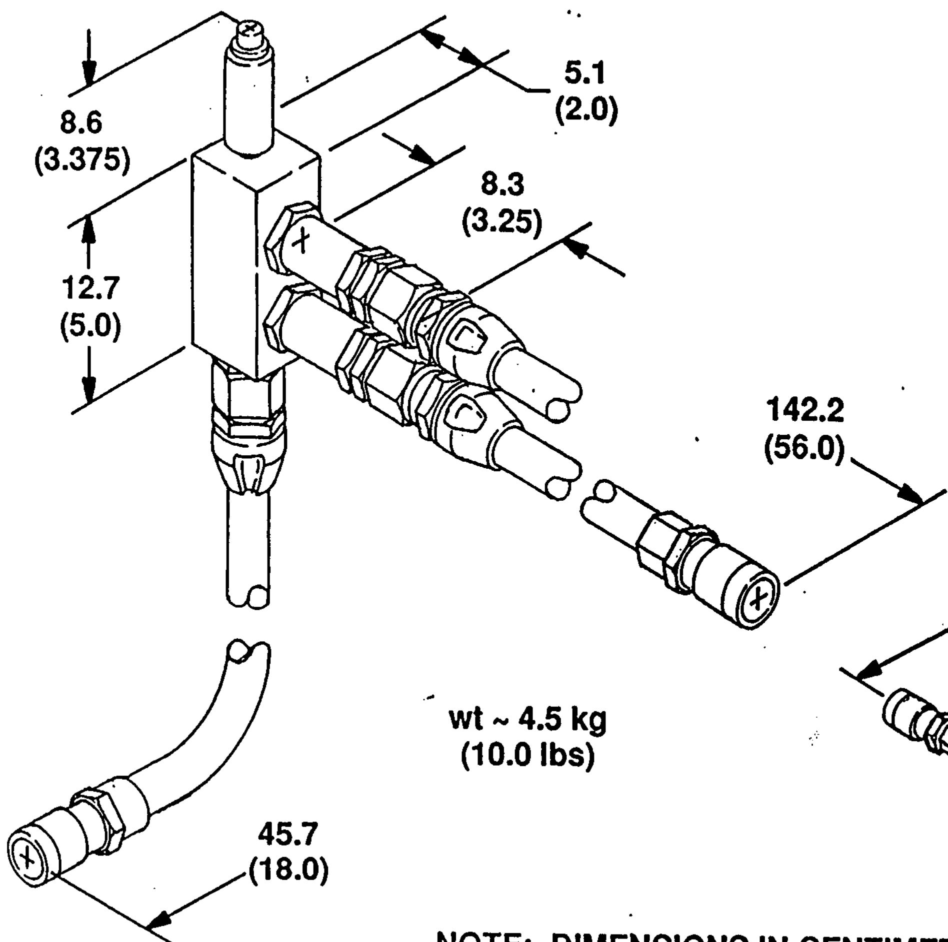
FIGURE 46

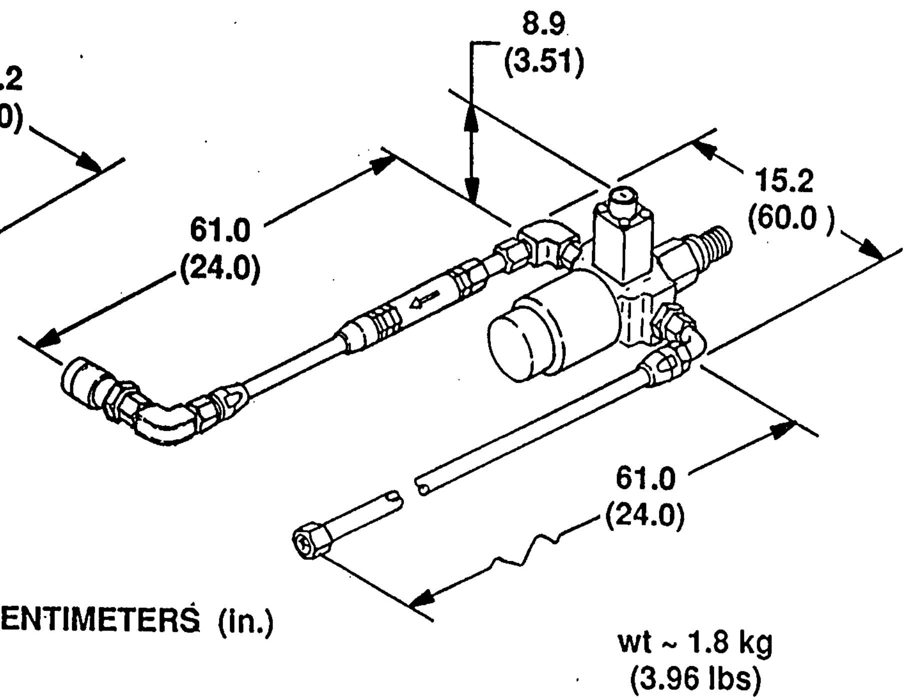


NOTE: DIMENSIONS IN CENTIMETERS (In.)

FURNACE POWER DISTRIBUTOR
(SHOWN MOUNTED)

FIGURE 47





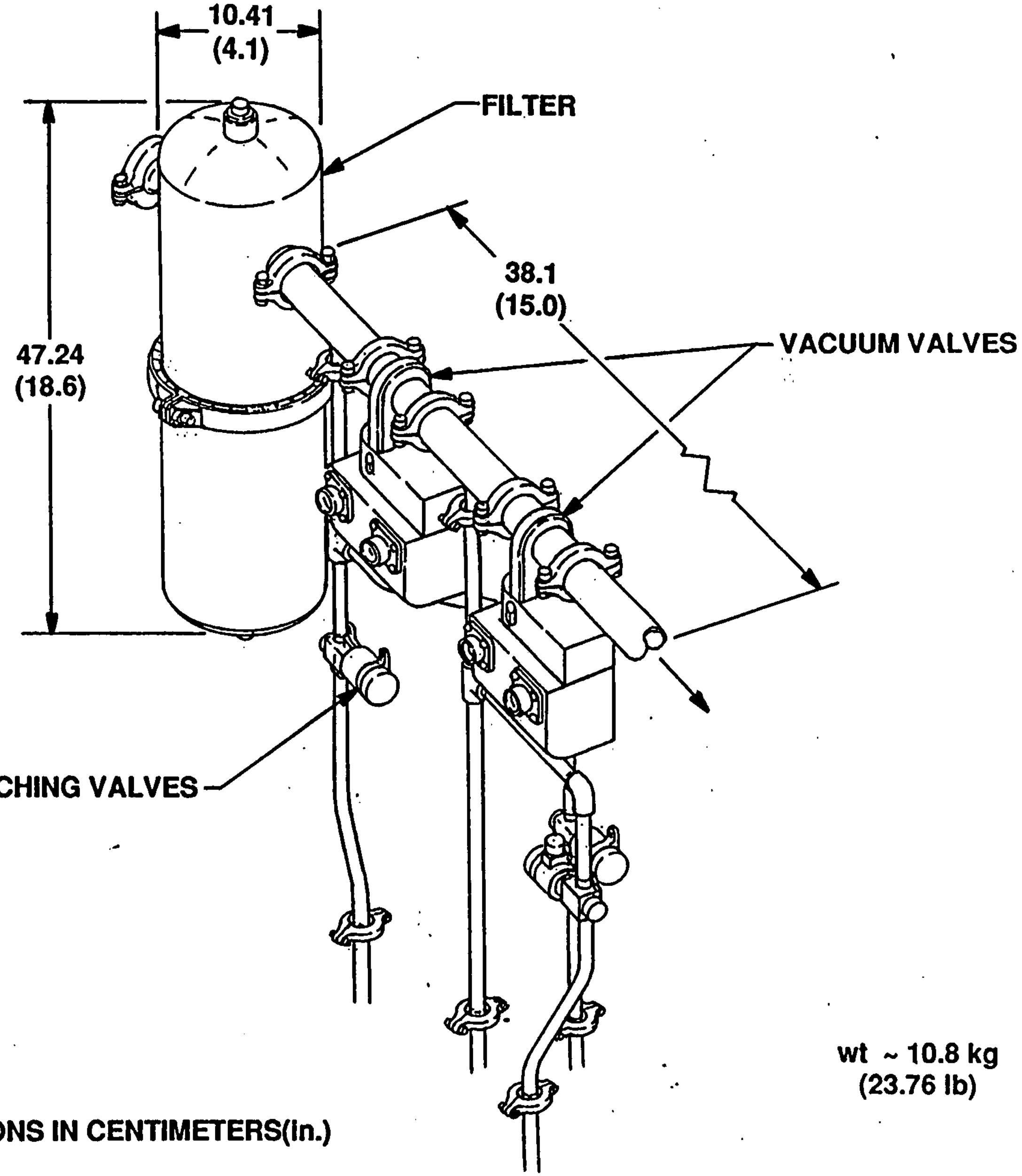
NOTE: DIMENSIONS IN CENTIMETERS (in.)

FURNACE RELIEF VALVE MANIFOLD

FIGURE 48

FURNACE GAS SUPPLY
VALVE ASSEMBLY

FIGURE 49

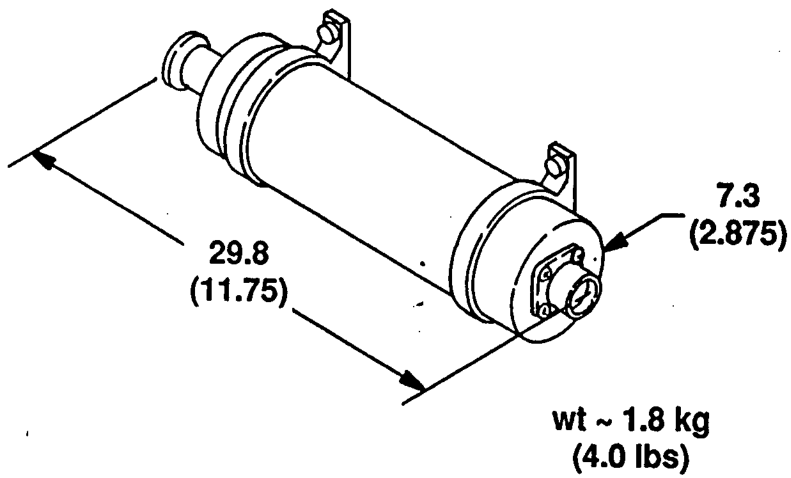


NOTE: DIMENSIONS IN CENTIMETERS(in.)

VACUUM FILTER VENT MANIFOLD

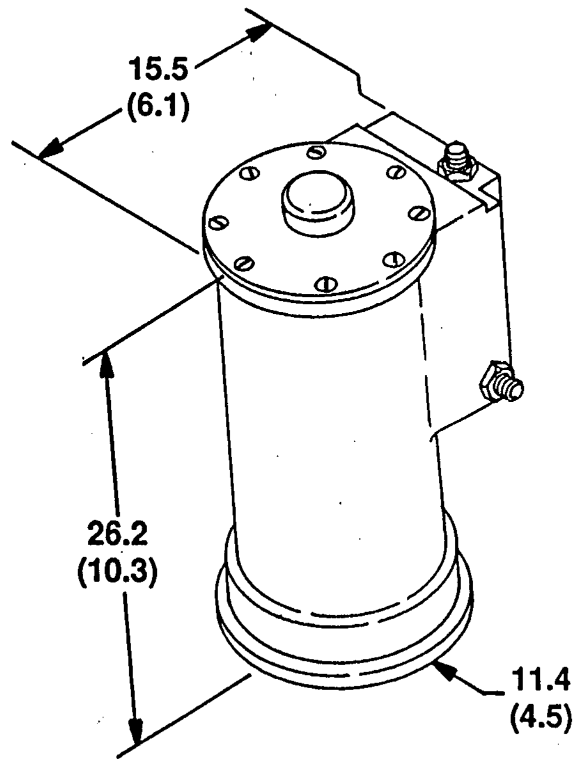
FIGURE 50

NOTE: DIMENSIONS IN CENTIMETERS (in.)



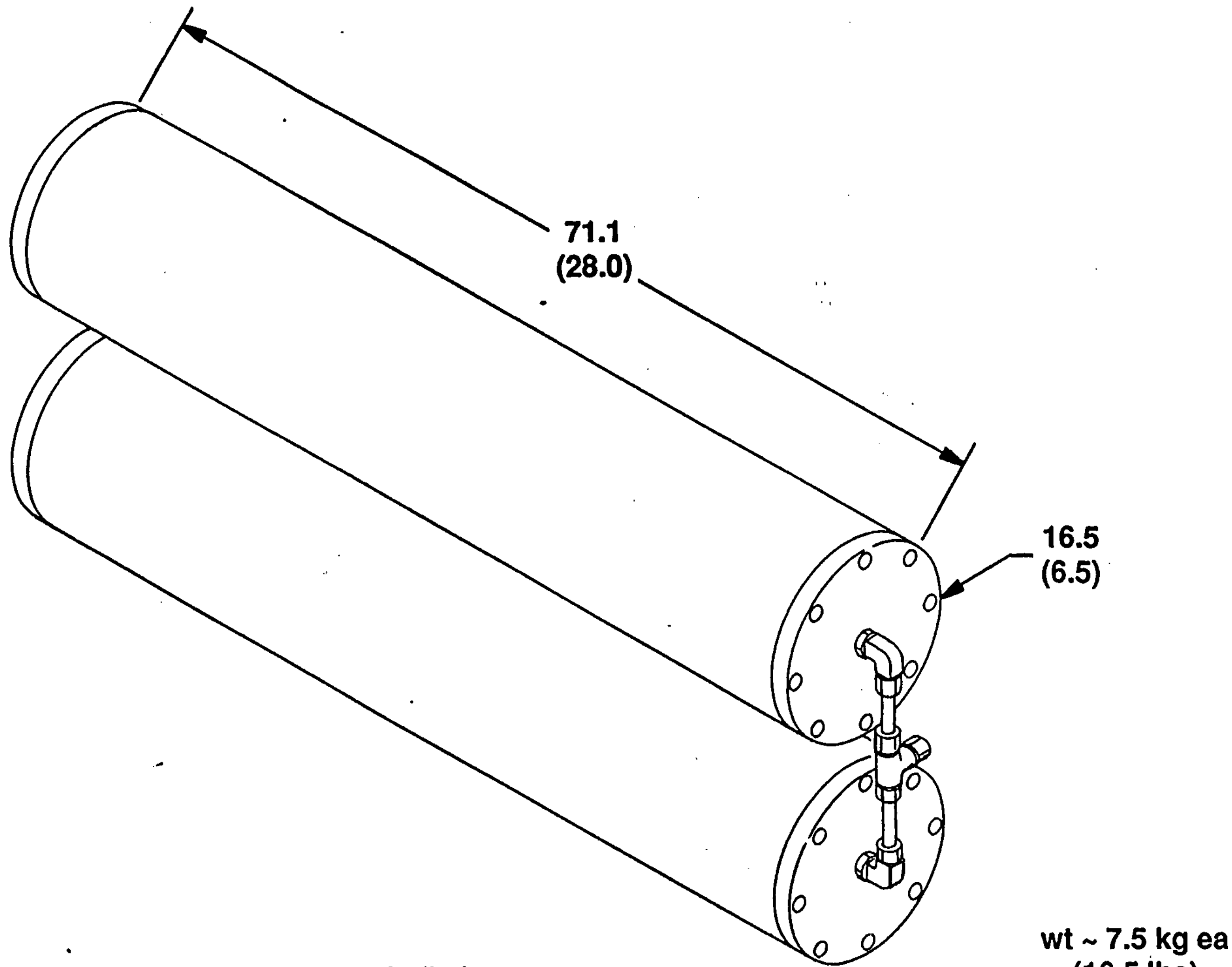
HI-RES VACUUM SENSOR
PRESSURE CONTROL

FIGURE 51



PRESSURE CONTROL
VACUUM PUMP

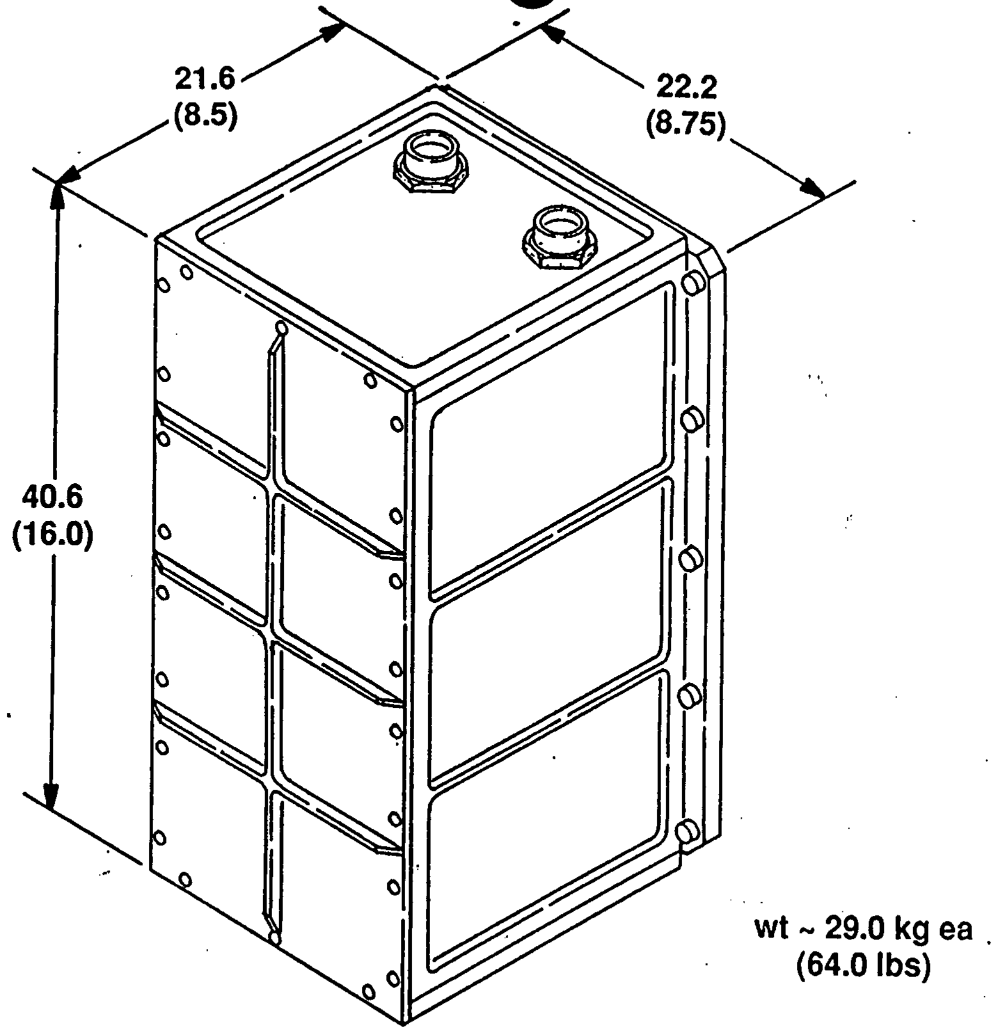
FIGURE 52



NOTE: DIMENSIONS IN CENTIMETERS (In.)

GAS PRESSURE CONTROL
STORAGE VESSELS

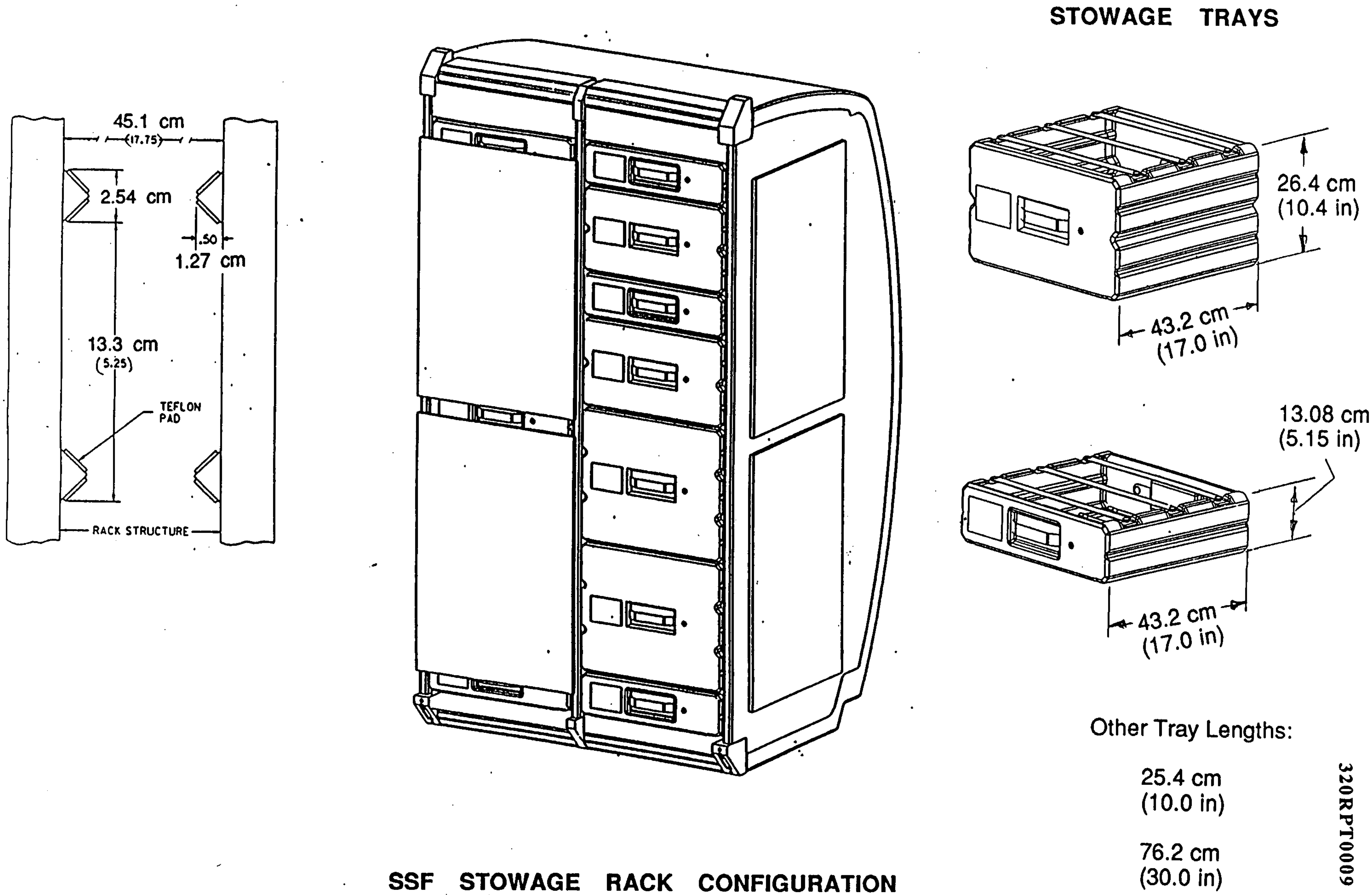
FIGURE 53



NOTE: DIMENSIONS IN CENTIMETERS (in.)

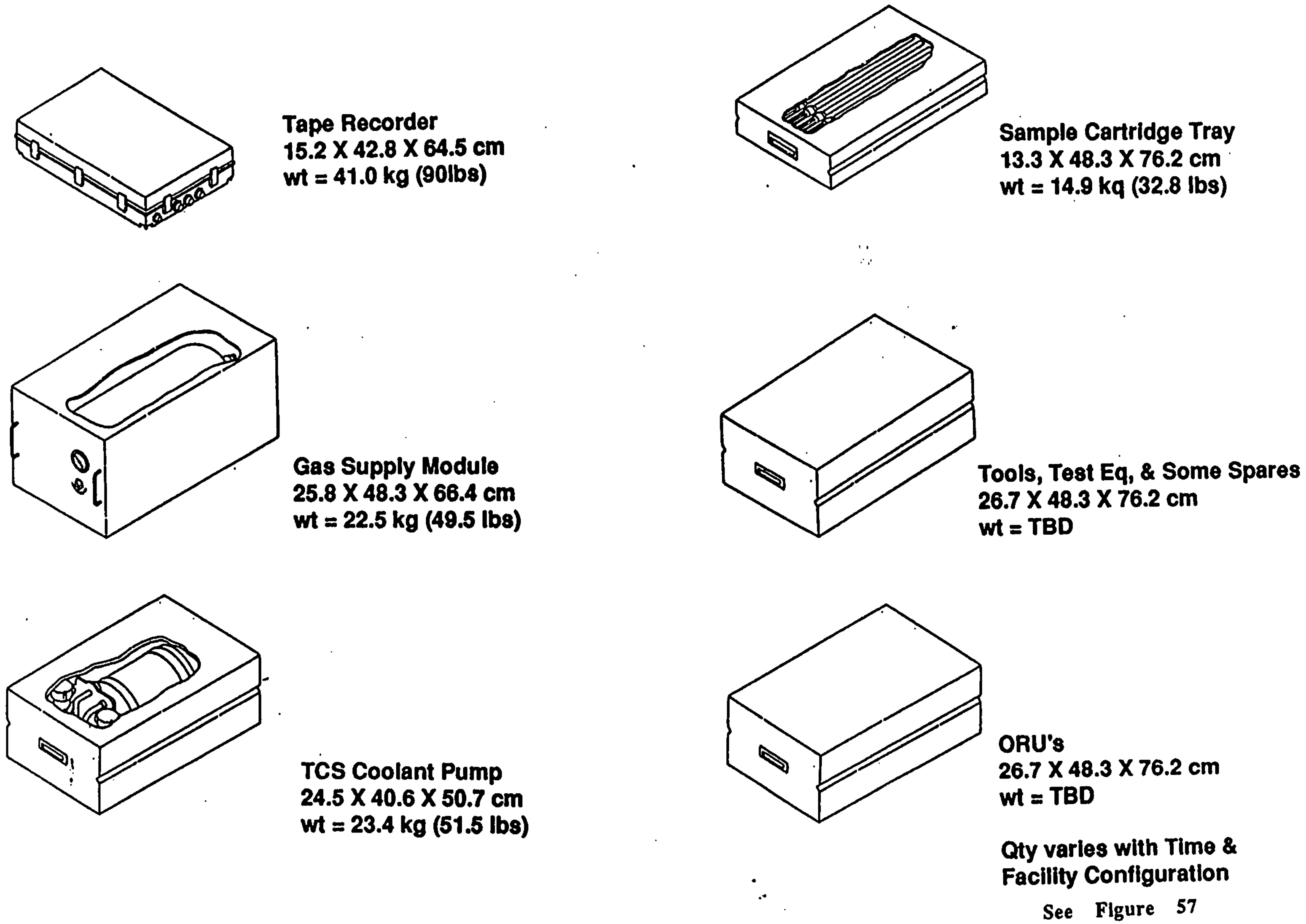
FURNACE CONTROL UNIT AND
FURNACE ACQUISITION UNIT

FIGURE 54



SSF STOWAGE RACK CONFIGURATION

FIGURE 55



INITIAL DEPLOYMENT
FACILITY SPARES / EQUIPMENT LIST

FIGURE 56

LEGEND - FIGURE 57
SSFF RESUPPLY MASS

1 - CORE COMPUTER / ELECTRONICS
Four possible units in this category would be subject to failure every 1.25 years. The chart will show a different box being changed (resupplied) starting with the CCU (29 kg), and then rotating to the CMCU (20 kg), Contamination Electronics (18 kg), and the Video Processor (29 kg).

2 - EXPERIMENT COMPUTERS
Three possible electronic units in the experiment rack would be subject to failure every 1.5 years. They are the FCU (29 kg), the FAU (29 kg), and the DMCU (20kg). The chart will show a constant 29 kg unit being resupplied each interval.

3 - 1.75 YEAR CORE & EXPERIMENT RACK COMPONENTS
This entry will consist of four hardware items summed together. They are the Coolant Control Valve Assembly (12.5 kg), a Power Conditioning Bank (23.6 kg), an ER Inlet Coolant Control Assembly (6.2 kg), and a Vacuum Valve (2.0 kg). Every other interval the core Coolant Control Assembly will be changed to the Coolant Return Valve Assembly (8.4 kg), the other items remain unchanged.

4 - CORE COOLANT PUMP & VACUUM FILTER
This entry will consist of the TCS Coolant Pump (23.4 kg) and the ER Vacuum Filter (3.6 kg) being changed (resupplied) as an ORU every 2.0 years.

5 - GAS CONTROL ASSEMBLY, HARD DRIVE, AND POWER DISTRIBUTION BOX
This entry will consist of the Gas Control Tray (10.5 kg), the Hard Drive (2.0 kg), and the Power Distribution Box (30 kg) being resupplied as an ORU every 2.25 years.

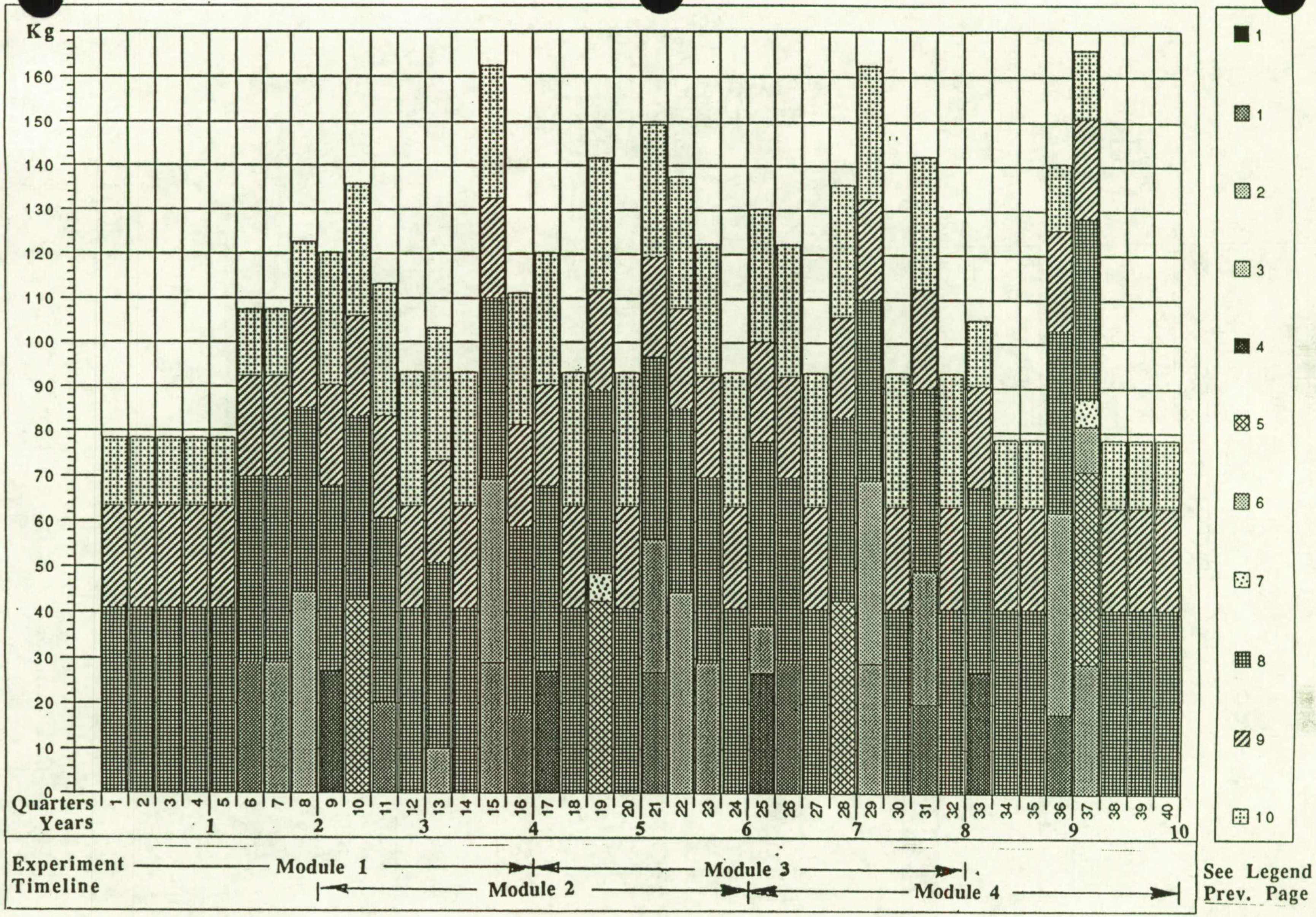
6- COLD PLATES
This entry consists of a core rack cold plate (6.0 kg) and an experiment rack cold plate (4.0) being resupplied every 3.0 years

7 - RPCM
This entry on the chart accounts for the ORU change out of an RPCM (6.0 kg) every 4.5 years.

8 - TAPE RECORDER
This entry on the chart accounts for a continuous resupply need for the Tape Recorder unit (41 kg).

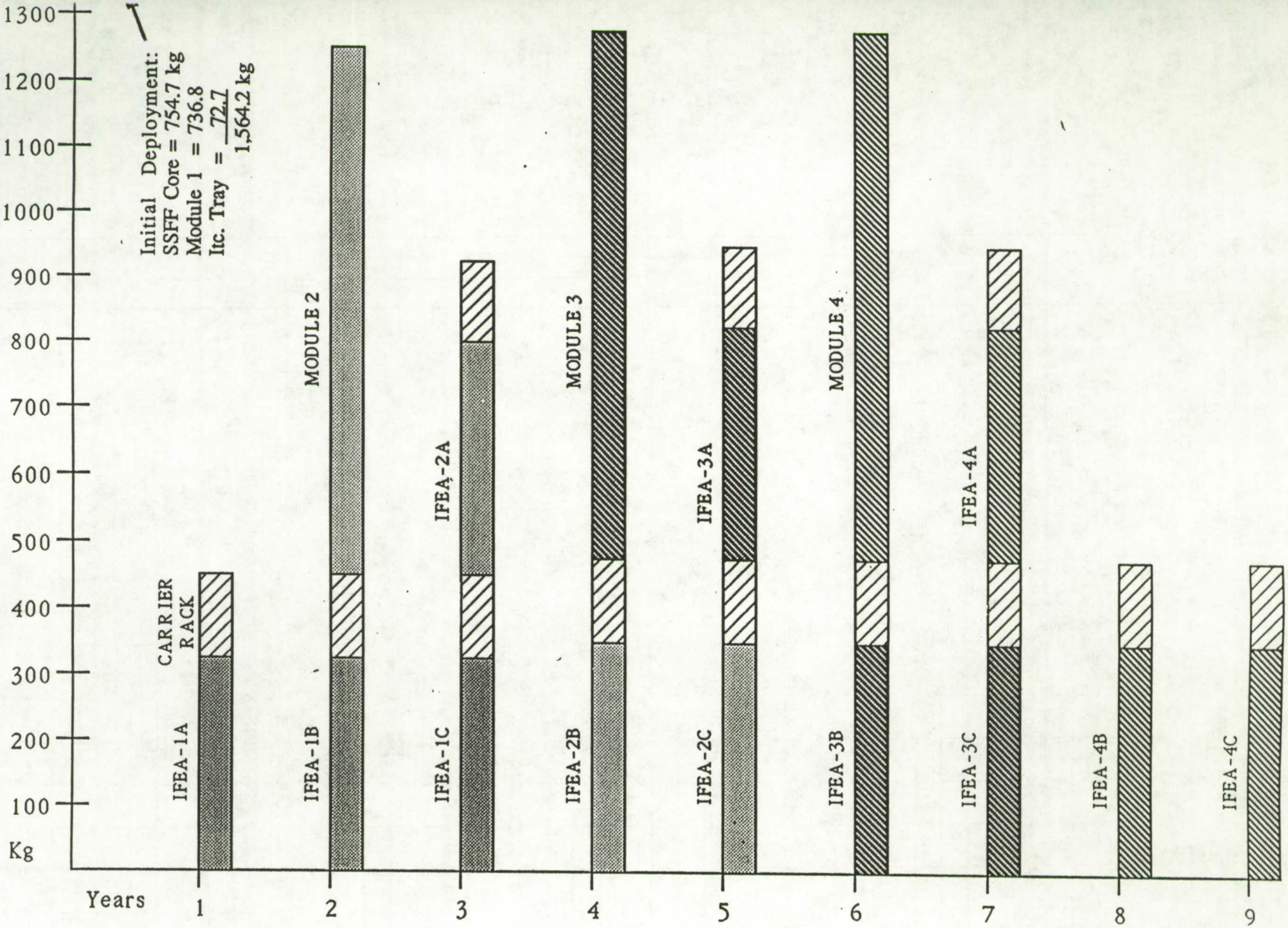
9 - GAS SUPPLY MODULE
This entry accounts for a continuous resupply need for the Gas Supply Module (22.5 kg).

10 - SAMPLE CARTRIDGES
This entry represents a 14.9 kg container of samples being supplied for each furnace module present.



SSFF
RESUPPLY MASS HISTORY

FIGURE 57



SSFF
EXPERIMENT MODULE
FLIGHT HISTORY

FIGURE 58

6.0 ORU OPERATIONAL SCENARIOS / FUNCTIONAL OBJECTIVES

This section of the ORU study report will provide additional insight into the overall on-orbit resources and astronaut time required for maintenance and repair operations. The functional objective requirements, normally filled out on a lengthy tabular format, will be presented here in an abbreviated form for the seven major maintenance tasks as described in Table 15 and in the legend to Figure 57. This form will be used because there are basically no other dependent operations (other than the availability of the astronaut time and in some cases the maintenance work station) or delays necessary, once repairs are initiated. The sequence, therefore, becomes a continuous string of operations for which a sequential time estimate can be provided. The sequence of steps will all start from a point in time when the facility has reached a shut down condition. Since there will be a requirement not to enter a rack with power on in that rack, the shut down most likely can not be effected until the furnace has completed cool down to the point water flow can be discontinued. If repairs are required in the core rack, then it might be necessary for the cool down to have also reached touch temperature on certain equipment items. The time delay for this has not been determined, but a note has been made in those cases where it could be considered a factor. The other human factors and program maintenance aspects of each ORU replacement would require a considerable more detailed analysis to requirements in References 3, 4, & 5 than can be made herein.

The maintenance tasks shown in Table 15 were developed from the MTBF data presented in Section 4.0. They do not include the ORU repairs described for Furnace Module 1 in Reference 10 or the routine operational tasks indicated in Figure 57 which include sample replacement and tape recorder change out. There will undoubtedly be other unplanned maintenance and repair operations which have not been taken into account; however for this phase of the facility planning the seven intervals covered should give a fair idea as to how well the concept meets the "easily maintainable" requirement. It will also offer insight into failure rates as a function of the degree of ORU complexity and whether smaller, larger, or more appropriate packaging could be provided. A strong consideration for on orbit repair seems warranted based on the likelihood of numerous minor failures at the board level in the more complex electronic assemblies. The FO's reported here are all developed based on an assumption that every hardware element is an ORU. Several of the components noted in Table 15, however, have been designated in Section 4.0 as SRU's and could conceivably be repaired in orbit. The detail sequence of steps for SRU repairs will not be developed herein since that approach would have to be agreed to by the SSF program and, in most cases, requires a greater degree of design development than was required to be produced by this contract.

TABLE 15 - SSFF ORU FUNCTIONAL OBJECTIVES

FO No.	FO Name	MTTR	Repair Time Interval
1	Change: a Core Computer	128 min.	Every 1.25 years
2	Change: an Experiment Computer	141 min.	Every 1.50 years
3	Change: a TCS Flow Ctrl Assy a Pwr Cond. Bank an ER Vacuum Valve an ER Flow Ctrl Assy	293 min.*	Every 1.75 years
4	Change: the TCS Pump Package the ER Vacuum Filter	220 min.*	Every 2.0 years
5	Change: the Gas Ctrl Assy the Hard Drive the Pwr Distr. Box	296 min.*	Every 2.25 years
6	Change: a CR Cold Plate an ER Cold Plate	335 min.	Every 3.0 years
7	Change: an RPCM	74 min.	Every 4.5 years

* - Indicates operational repair estimates based on the support of two men.

FO Number 1 - Change Out Of A Core Computer/Electronics Box

This task could include either the change out of the CCU (Figure 38), the CMCU (Figure 39), the Monitor/keyboard (Figure 30), or the Contamination Electronics (Figure 28). The video processor and the tape playback would be additional electronics elements that would reduce the potential service life interval further if they are included in the facility outfitting. Since the first two experiment modules will not need these system they have been left out of the resupply mass estimates and this section. For the follow time estimate replacement of the CCU has been taken as a representative mean average computer replacement operation by one man.

Step	Activity	Time Est.(min)
1	Remove tools and mobility restraints from storage and affix to adjacent rack for repair operations. Prep replacement CCU.	20.0
2	Release core rack upper latch and rotate rack down.	1.0
3	Remove one rear access panel on the CCU side and stow.	8.0
4	Remove the left side access panel and stow.	8.0
5	Disconnect CCU power and data interface cables, secure from interference with box removal.	6.0
6	Unbolt CCU from its cold plate. Attach handling strap and maneuver from rack. Secure in temporary location.	10.0
7	Take replacement unit and locate on cold plate. Using a torque wrench torque bolts to required value.	15.0
8	Carefully checking cable ID's and keying, reinstall power and data connections to new unit.	10.0
9	Check rack interior for any anomalies, replace rear access panel and torque captive fasteners.	15.0
10	Replace side access panel and torque fasteners.	12.0
11	Rotate rack back upright and engage latch.	1.0
12	Stow the tools and repair equipment.	12.0
13	Check out replacement unit on next power up.	-----
	Total MTTR	128.0

FO NUMBER 2 - Change Out Of An Experiment Rack Computer

This task would include either the change out of the FAU / FCU (Figure 54) or the DCMU. The DCMU is assumed to be located below the experiment rack support beam and is packaged in a box similar to the essentials power supply shown in Figure 23. For the following time estimate, change out of the FCU is assumed to be a reasonable mean representative of this group and is based on one man operations.

Step	Activity	Time Est.(min)
1	Remove tools and mobility restraints from storage. Affix MR to adjacent rack for repair operations. Prep replacement FCU and tools in Maintenance Workstation.	30.0
2	Release furnace rack upper latch and rotate rack down.	1.0
3	Remove rear access panel on side of FCU and stow.	8.0
4	Disconnect TCS lines from FCU cold plate.	0.5
5	Disconnect FCU power and data interface cables, secure from interference with box removal.	5.0
6	Unbolt FCU support plate assembly from the rack mount frame. Attach handling strap and maneuver from rack.	8.0
7	Transport assembly to the maintenance work station. Install in work restraints.	10.0
8	Unbolt FCU from cold plate/support plate assembly and install replacement unit using a torque wrench to tighten fasteners.	20.0
9	Using handling strap return assembly to rack mounting location. Reinstall plate assembly observing required orientation.	20.0
10	Carefully checking cable ID's and keying, reinstall power and data connections to new unit.	10.0
11	Reconnect TCS coolant lines.	0.5
12	Check rack interior for any anomalies, replace rear access panel and torque captive fasteners.	15.0
13	Rotate rack back upright and engage latch.	1.0
14	Stow the defective unit and repair equipment.	12.0
15	Check out replacement unit on next power up.	------
	Total MTTR	141.0

FO NUMBER 3 - Change Out Of 1.75 Year Core Rack And Experiment Rack Components

This task would include the change out of two components in both the core and experiment racks. The operations will be assumed to be performed in series starting with the core rack. The TCS Coolant Control Valve Assembly (Figure 16) and a Power Conditioning Bank (Figure 24) are the two elements to be changed in the core. The Furnace Coolant Inlet Control Assembly (Figure 42) and one of the two Vacuum Control Valves shown in the manifold (Figure 50) are assumed to be the experiment elements to be replaced. Figures 10, 11 & 40 are helpful in finding the location of these components within the two racks. For the following time estimates, change out of the units is assumed to be by two men in series operations.

Step	Activity	Time Est.(min)
1	Remove tools and mobility restraints from storage. Affix MR's to adjacent racks (to core) for repair operations. Prep replacement Coolant Control Assembly (remove from stowage drawer and secure in work area).	35.0
2	Remove cover plates on the core rack at the two tray locations and secure out of the way.	6.0
3	Disconnect the power and control lines at the front connector plate of the power bank and secure out of the way.	4.0
4	Release the core rack upper latch and rotate rack down.	1.0
5	Remove the rear access panels on both sides and stow.	12.0
6	Disconnect TCS lines from the coolant valve assembly and the power bank cold plates and stow out of the way.	4.0
7	Disconnect the power and data lines from the coolant tray and the four power bank output lines.	6.0
8	Rotate the core rack back to the upright position.	1.0
9	From the front of the coolant tray release the two tray locking screws and being careful not to catch any lines pull the tray forward till its catch is engaged.	4.0
10	Disconnect the coolant tray from its slide support brackets, and using a handling strap maneuver it to the stowage drawer.	8.0
11	Pick up the replacement tray from its secured location and install on the slides torqueing the fasteners to the required value.	12.0

FO NUMBER 3 (cont.)		Time Est.(min)
12	Feeding the attached hose(s) thru the rack, slide the tray in and secure the slide's locking fasteners.	6.0
13	Release the power conditioning tray locking fasteners and slide that tray out till its catch engages.	4.0
14	Release the fasteners holding the bank to the slide support brackets.	6.0
15	Lift the bank free of the rack with a handling strap and carry to the storage location. Exchange this bank with the replacement.	10.0
16	Install the new bank reversing steps 13 and 14.	15.0
17	Reinstall the power connectors on the front panel of the bank.	6.0
18	Fold the rack down and reinstall the connectors and coolant lines on the rear of the bank and coolant control tray.	12.0
19	Inspect the rack interior for any anomalies, then reinstall the rear access panels and the front close out plates.	25.0
20	Moving the work restraints to the racks adjacent to the experiment rack, fold the rack down and remove the rear access panels.	30.0
21	Disconnect the coolant lines and the power and data connector from the Coolant Inlet Control Assembly.	8.0
22	Unbolt the Coolant Inlet Control Assembly from the rack mount frame. Attach handling strap and maneuver from rack.	6.0
23	Remove the power and data lines from the vacuum valve to be replaced.	1.0
24	Remove the two end clamps from the valve and remove it from the rack.	4.0
25	Transport the faulty assemblies to the stowage rack and exchange with the replacement units.	12.0
26	Reinstall the new units reversing steps 21 - 24	25.0
27	Check rack interior for any anomalies, replace rear access panel and torque captive fasteners.	15.0
28	Rotate rack back upright and engage latch. Stow the repair equipment.	15.0
29	Check out replacement units in both core and experiment racks on next power up.	------
	Total MTTR	293.0

FO NUMBER 4 - Change Out Of Core Rack Coolant Pump And Experiment Rack Vacuum Filter

This task would involve the change out of components in both the core and experiment racks. The operations will be assumed to be performed in series starting with the core rack. The TCS Coolant Pump Assembly (Figure 15) in the core, and the Vacuum Filter shown in the manifold (Figure 50) are assumed to be replaced every 2.0 years. Figures 10, & 40 are helpful in finding the location of these components within the two racks. For the following time estimates, change out of the units is assumed to be by two men in series operations.

Step	Activity	Time Est.(min)
1	Remove tools and mobility restraints from storage. Affix MR's to adjacent racks (to core) for repair operations. Prep replacement Coolant Pump Assembly (remove from stowage drawers and secure in work area).	30.0
2	Remove cover plate on the core rack at the pump tray location and secure out of the way.	4.0
3	Disconnect the power and control lines at the connector plate on the pump and secure out of the way.	4.0
4	Release the core rack upper latch and rotate rack down.	1.0
5	Remove the rear access panel on the pump side and stow.	6.0
6	Disconnect TCS lines from the coolant pump assembly and secure.	6.0
7	Rotate the core rack back to the upright position.	1.0
8	From the front of the pump tray release the two tray locking screws and being careful not to catch any lines pull the tray forward till its catch is engaged.	4.0
9	Disconnect the coolant tray from its slide support brackets, and using a handling strap maneuver it to the stowage drawer.	8.0
10	Pick up the replacement tray from its secured location and install on the slides torqueing the fasteners to the required value.	12.0
11	Feeding the attached hose(s) thru the rack, slide the tray in and secure the slide's locking fasteners.	6.0
12	Reinstall the electronic connectors on the front panel of the pump.	5.0
13	Fold the rack down and reinstall the rear coolant lines.	10.0
14	Inspect the rack interior for any anomalies, then reinstall the rear access panel and the front close out plate.	15.0

FO NUMBER 4 (cont.)		Time Est.(min)
15	Moving the work restraints to the racks adjacent to the experiment rack, fold the rack down and remove the rear access panels.	30.0
16	Disconnect the inlet and outlet lines from the filter housing assembly.	8.0
17	Unbolt the filter from the rack mount frame. Attach a handling strap and maneuver from rack.	8.0
18	Transport the faulty assembly to the stowage rack and exchange with the replacement unit.	12.0
19	Reinstall the new unit reversing steps 16, and 17.	20.0
20	Check rack interior for any anomalies, replace rear access panel and torque captive fasteners.	15.0
21	Rotate rack back upright and engage latch. Stow the repair equipment.	15.0
22	Check out replacement units in both core and experiment racks on next powered up operation.	-----
	Total MTTR	220.0

FO NUMBER 5 - Change Out Of Core Rack Gas Control Assembly, Hard Drive, And Power Distribution Box

This task would involve the change out of components only in the core rack. The GDS Gas Control Assembly (Figure 29), the Hard Drive (Figure 32), and the Power Distribution Box (Figure 22) are assumed to be replaced every 2.25 years. Figures 11,12 & 13 are helpful in finding the location of these components within the rack. For the following time estimates, change out of the units is assumed to be performed by two men in series operations.

Step	Activity	Time Est.(min)
1	Remove tools and mobility restraints from storage. Affix MR's to adjacent racks (to core) for repair operations. Prep replacement Gas Control Assembly (remove from stowage drawers and secure in work area).	30.0
2	Open the access door in the face of the Gas Control Assembly face plate and disconnect the gas supply QD.	4.0
3	Remove the cover plates on the core rack at the hard drive and power distributor locations and secure out of the way.	6.0
4	Release the core rack upper latch and rotate rack down.	1.0
5	Remove the rear access panels and stow.	12.0
6	Disconnect TCS lines from the power distribution tray assembly and the hard drive tray and secure.	4.0
7	Disconnect the power and data lines from the each of the three trays (components) to be serviced and secure appropriately.	8.0
8	Rotate the core rack back to the upright position.	1.0
9	From the front of the gas tray release the tray locking screws and careful pull the tray slides forward till its catch is engaged.	4.0
10	Disconnect the gas tray from its slide support brackets, and using a handling strap maneuver it to the stowage drawer.	8.0
11	Pick up the replacement tray from its secured location and install on the slides torqueing the fasteners to the required value.	12.0
12	Slide the tray in and secure the face plate's locking fasteners.	6.0
13	Working through the panel opening, unbolt the hard drive from its cold plate and install a handling strap.	6.0
14	Transport the faulty assembly to the stowage rack and exchange with the replacement unit.	12.0

FO NUMBER 5 (cont.)		Time Est.(min)
15	Install the new unit torqueing the mounting fasteners.	10.0
16	Release the distributor tray locking fasteners and slide that tray out till its catch engages.	4.0
17	Unbolt the tray from its slide support brackets and install a handling strap.	8.0
18	Transport the assembly to the maintenance work station. Install in work restraints.	8.0
19	Release the two RPCM locks and using a tool handle jack them off the distributor connectors.	6.0
20	Unbolt the distributor from its cold plate.	8.0
21	Transport the faulty assembly to the stowage rack and exchange with the replacement unit.	15.0
22	Reinstall the new distributor and RPCM's on the tray assembly and return the tray to the rack slides.	60.0
23	Slide the tray in and secure the locking fasteners.	6.0
24	Rotate the rack down again and carefully reconnect the power and data lines to the three trays.	15.0
25	Reconnect the TCS coolant lines to the two electronics trays.	2.0
26	Check rack interior for any anomalies, replace rear access panels and the front close outs, torqueing the captive fasteners.	25.0
27	Rotate rack back upright and engage latch. Stow the repair equipment.	15.0
28	Check out replacement units on next powered up operation.	-----
	Total MTTR	296.0

FO NUMBER 6 - Change Out Of A Core Rack And Experiment Rack Cold Plate

This task would involve the change out of components in both the core and experiment racks. The operations will be assumed to be performed in series starting with the core rack. Statistically i is felt at least one typical TCS Cold Plate Assembly (Figure 18) in each rack will develop a problem requiring its replacement every 3.0 years. Figures 10 & 40 are helpful in finding the location of these components within the two racks. For the following time estimates, change out of the units (one under the CMCU and the other under the FAU) is assumed to be performed by one man in a series operation.

Step	Activity	Time Est.(min)
1	Remove tools and mobility restraints from storage. Affix MR's to adjacent racks (to core) for repair operations. Prep replacement Cold Plate Assembly (remove from stowage drawer and secure it in the maintenance work station).	30.0
2	Remove the cover plate on the core rack at the CMCU tray location and secure out of the way.	4.0
3	Disconnect the TCS coolant lines at the front of the cold plate and secure out of the way.	3.0
4	Release the core rack upper latch and rotate rack down.	1.0
5	Remove the rear access panel on the CMCU side and stow.	8.0
6	Disconnect the other TCS line from the cold plate along with the power and data lines to the CMCU and secure.	20.0
7	Rotate the core rack back to the upright position.	1.0
8	From the front of the tray release the two tray locking screws and being careful not to catch any lines pull the tray forward till its catch is engaged.	4.0
9	Disconnect the entire tray from its slide support brackets, and using a handling strap maneuver it to the maintenance work station.	10.0
10	Unbolt the CMCU from the cold plate/tray and secure it.	6.0
11	Unbolt the cold plate from the tray backing plate and replace it with the new unit. After capping the defective plate stow it in a sealed bag and place it in storage for return to Earth.	20.0
12	Reinstall the CMCU and carry the assembly back to the rack.	12.0
13	Reinstall the tray on the slide supports and stow the tray securing its locking screws.	20.0

FO NUMBER 6 (cont.)		Time Est.(min)
14	Reinstall the front TCS coolant line, rotate the rack down and reinstall the rear coolant line.	4.0
15	Carefully reconnect the power and data connectors on the CMCU.	30.0
16	Inspect the rack interior for any anomalies, then reinstall the rear access panel, rotate the rack and install the front close out plate.	20.0
17	Moving the work restraints to the racks adjacent to the experiment rack, fold the rack down and remove a rear access panel.	25.0
18	Disconnect the inlet and outlet lines from the FAU cold plate.	1.0
19	Disconnect the power and data lines from the FAU and secure.	10.0
20	Unbolt the FAU assembly from the rack mount frame. Attach a handling strap and maneuver from rack.	6.0
21	Transport the faulty assembly to the maintenance work station.	10.0
22	Remove the FAU from the cold plate.	6.0
23	Remove the cold plate from the structural mounting plate.	8.0
24	Install the new unit reversing steps 21, and 22, and 23.	20.0
25	Install the repaired assembly on the mount frame and reconnect the power and data lines.	25.0
26	Reconnect the coolant lines to the cold plate.	1.0
27	Check rack interior for any anomalies, replace rear access panel and torque captive fasteners.	15.0
28	Rotate rack back upright and engage latch. Stow the repair equipment.	15.0
29	Check out replacement units in both core and experiment racks on next powered up operation.	------
	Total MTTR	335.0

FO NUMBER 7 - Change Out Of A Core Rack RPCM

This task would involve the change out of one of the two RPCM's in the core rack. MTBF data in Section 4.0 estimated one of the RPCM Assemblies (Figure 21) will develop a problem requiring its replacement after approximately 4.5 years of service. Figure 11 is helpful in finding the location of these components within the rack. For the following time estimates, change out of a unit is assumed to be performed by one man.

Step	Activity	Time Est.(min)
1	Remove tools and mobility restraints from storage. Affix MR's to adjacent racks (to core) for repair operations. Prep replacement RPCM Assembly (remove from stowage drawer and secure it in the work area).	30.0
2	Remove the cover plate on the core rack at the RPCM tray location and secure it out of the way.	4.0
4	Release the RPCM latch and using the handle tool jack the defective unit off the distributor connector. Stow the unit for shipping.	10.0
5	Align the replacement unit with the guide rail and using the handle jack the unit onto the distributor connector. Lock it in place and remove the handle.	8.0
6	Check rack interior for any anomalies, replace the front panel and torque captive fasteners.	10.0
7	Stow the repair equipment.	12.0
8	Check out the replacement unit on the next powered up operation.	-------
	Total MTTR	74.0

SPACE STATION FURNACE FACILITY TECHNICAL REPORT

INTER-RACK DEMONSTRATION UNIT

Contract No. NAS8-38077

May 1992
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B Rack Interconnect Demonstration Unit Drawings

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FOREWORD

This effort was performed by Teledyne Brown Engineering under contract to NASA's Marshall Space Flight Center (MSFC). The study was led by Jerry LeCroy, and principal contributors include Mark Payne, Greg Mitchell, John Boyles, Ken Britton, Jay Medeiros, Shelley Le Roy, and Dan Deitz.

Acronym/Abbreviation List

CGF Crystal Growth Furnace
ECS Environmental Control System
FDS Fire Detection and Suppression
ICD Interface Control Document
ISPR International Standard Payload Rack
MSFC Marshall Space Flight Center (NASA)
NASA National Air and Space Agency
PMZF Programmable Muti-Zone Furnace
SCRD Science Capabilities and Requirements Document
SSF Space Station Freedom
SSFF Space Station Furnace Facility
TBE Teledyne Brown Engineering
TCS Thermal Control System

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1.0 SCOPE

The purpose of the work performed under this study task was to develop a conceptual design for inter-rack fluid and electrical connections in the Space Station Furnace Facility (SSFF), and to demonstrate the feasibility of the concept. This report summarizes the concept design and trade studies, the construction details for the demonstration unit, and test results from the demonstration unit. The contract statement of work paragraph covering this effort follows:

> "The development model must demonstrate and prove the feasibility of the inter-rack connections dictated by the SSFF conceptual design. It may be necessary to build a separate demonstrator to prove the feasibility of the inter-rack connections."

2.0 EXECUTIVE SUMMARY

During this study Teledyne Brown Engineering (TBE) started with the complement of typical furnaces listed in the Science and Capability Requirements Document (SCRD) and the SSFF conceptual design as a baseline for services interconnections. This baseline used the concept of providing separate services to each experiment. When it became apparent that this baseline would not fit in the space allowed, a reduced-connection complement of services was developed that met the services requirements of the experiments, but shared the interconnections. This interconnect concept was implemented in a demonstration unit, which was used to determine the feasibility of the design approach.

Key issues in the concept design were providing an adequate cable count for payload power and data lines, and creating a realizable and maintainable design. The technical risk area which demanded development of a physical model to prove the interconnect system functionality was the requirement that Space Station racks be capable of being tilted out rapidly for access to the pressure hull behind the racks. Previous inter-rack cabling designs, such as those used on the Spacelab, are fixed in place and do not permit on-orbit behind-rack access without time consuming cable and fluid line removal. SSFF is a critical application of tilt-out compatible interconnects, due to the nature of the attached payloads. Most furnaces will contain sufficient energy during operation to represent a significant hazard if coolant flow were suddenly interrupted. The SSFF inter-rack connection architecture, then, should accept rack tilt-out without severing service connections to the experiment or to the other essential station services.

The concept design developed meets all defined functional requirements. No technology development will be required to perform detail design and fabrication of the SSFF rack interconnect design selected.

3.0 RACK INTERCONNECT SYSTEM REQUIREMENTS

3.1 Trade Study Summary

The first rack interconnect design developed by the TBE study team provided all available station services to as many as four concurrent experiments. Down-sizing of the station reduced the number of concurrently served experiments from four to two, and eliminated inert gas, high purity water, and waste gas handling services from the station service complement. The interconnect team reduced the complexity of the core facility design to reflect the simplified system requirements, and began laying out connector panels to support the remaining services. This first detailed layout required forty six (46) connectors on the core rack interface panel. It was judged to be unusable due to space restrictions on connector panels.

Several alternative layout schemes were considered in order to provide the required complement of fluid and electrical connections. All these architectures have in common that their connector panels exceeded the available rack panel space, and that the connectors were spaced too tightly to comply with human factors/serviceability requirements.

Based on analysis of the limited space available for connectors and additional data regarding changes to the space station service connection and rack design, the TBE rack interconnect design team developed a reduced connection set, intended to provide the service connections needed by experiments without violating space limitations or maintainability requirements. These layouts disclosed that adequate spacing of connectors and fluid fittings on the SSFF would require the equivalent area of three standard rack interface panels Figures 3.1-1 and 3.1-2 show layouts of connector panels to accept the identified interconnects on the core rack and experiment sides, respectively. Since the SSFF core payload rack must contain a substantial amount of electronic and Environmental Control System (ECS)/fluid system components, it is apparent that the lower half of the rack cannot be dedicated to interconnect panels. Also, the height required by a full-width connector panel on the payload rack would preclude mounting a full-height payload in the facility.

Two scrubs were made of the rack interconnect system to minimize the number of electrical and fluids interconnects between racks. These scrubs also changed the configuration of the experiment interconnect panels, so that the necessary mechanical and electrical connections could be accepted without using up rack height which may be needed by an experiment.

The first scrub further eliminated available SSF services which were unlikely to be needed by the SSFF Payloads, and responded to the deletion of the low-grade waste gas vent service. This scrub resulted in the connection list shown in Table 3.1-1 and the core rack interconnect layout shown in Figure 3.1-3. This layout occupies two half-width interface panels.

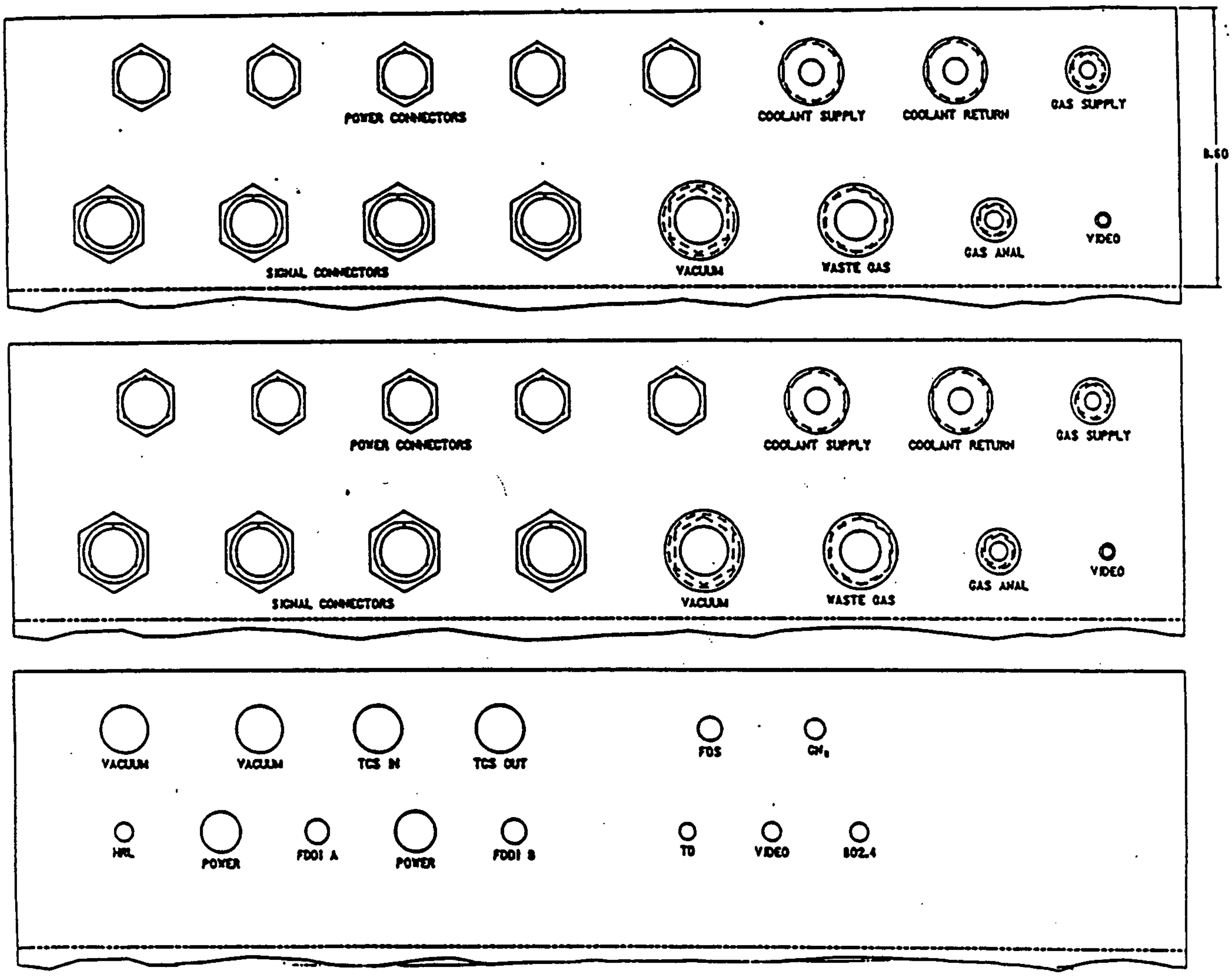


Figure 3.1-1 Initial Core Rack Interface Panel Layout

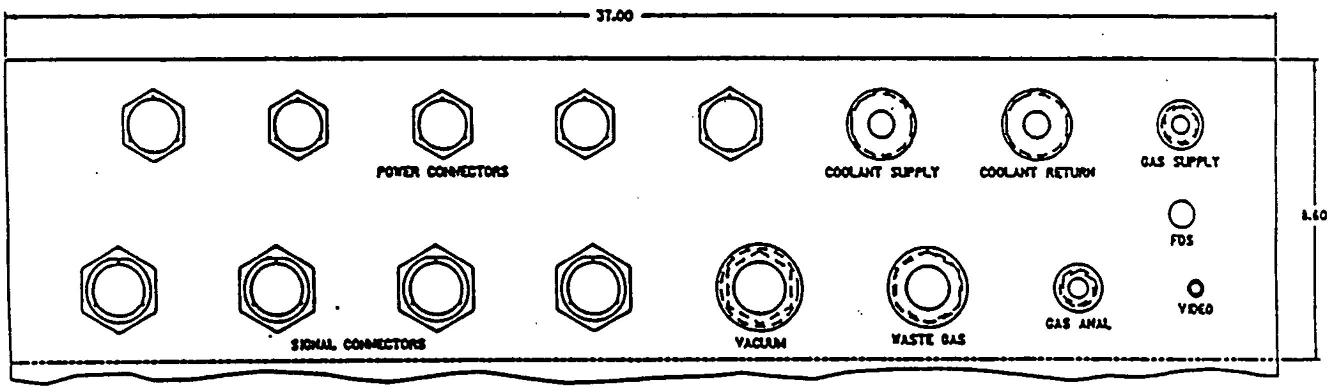


Figure 3.1-2 Initial Experiment Interface Panel Layout

Table 3.1-1 Scrubbed SSFF Interconnect Summary

	Core Rack Input	Core Rack Output	Furnace 1	Furnace 2
ECS Coolant				
Coolant In	1	1	1	1
Coolant return	1	1	1	1
Fluids				
Nitrogen	1			
SS Vacuum 1	1			
Fire Detection	1		1	1
Avionics Air	1		1	1
Experiment Gas Supply		1	1	1
Furnace Vacuum		1	1	1
Power				
Essentials Power		1	1	
6 KW feed	1			
Conditioned power		8	4	4
Signal				
FDDI	1			
Video	1	1	1	1
TD	1			
Furnace Data		2	1	1

Total Connectors	
Core Rack	26
Furnace 1	13
Furnace 2	12

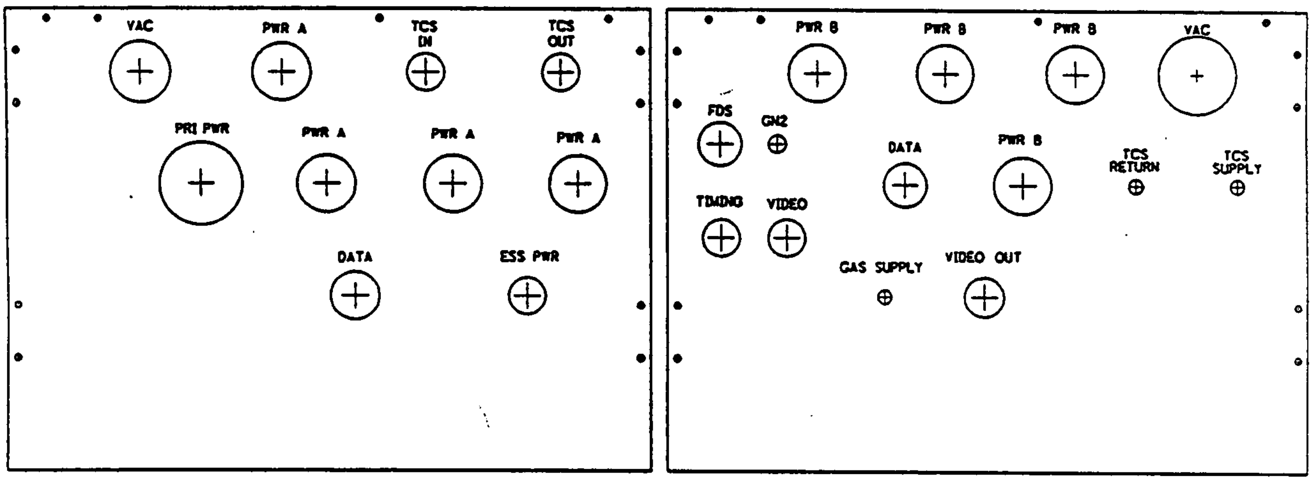


Figure 3.1-3 Reduced Service Core Rack Interface Panel Layout

Significant space and volume reductions were made by assuming distributed signal processing at the experiments, so that the core facility could receive necessary operations data over a single cable, rather than the five such cables required by experiments such as the Crystal Growth Furnace (CGF) furnace. This reduction reflects a change in SSFF service philosophy - instead of taking all possible signals in from any experiment and processing them in a core rack computer, the SSFF core would receive pre-processed data from experiment-side electronic interface units. The core computer could send time-line commands through an identified data interface to the experiment-side controller. Electronics at the experiment rack would provide signal conditioning and experiment specific control signals.

Since materials processing experiments typically operate with rather long time constants, multiplexing the telemetry from each experiment causes no problems with data acquisition rates, and reduces interface complexity. This would also place the signal conditioning circuits close to the experiment, which reduces system error due to electrical noise and line losses, particularly for low-level signals such as those from thermocouples and low-speed tachometers.

The second major reduction in the rack interconnect architecture was on the fluid connectors. The coolant and gas supply lines for the two supported experiments were placed in parallel, so that single ports are used at the core rack to supply both attached experiments.

3.2 SSF Service Interface Requirements

The SSFF will access virtually all available SSF services, including coolant, pressurant, vacuum, power, fire detection/suppression, fiber data bus, and video services. The rack interconnect design interfaces with those services at the common rack interface panel located at the base of the rack structure, as defined in SSP-41002-1. No exceptions were taken to the Space Station International Standard Payload Rack (ISPR) utility panel location or layout, as shown in Figures 3.2-1 and 3.2-2 .

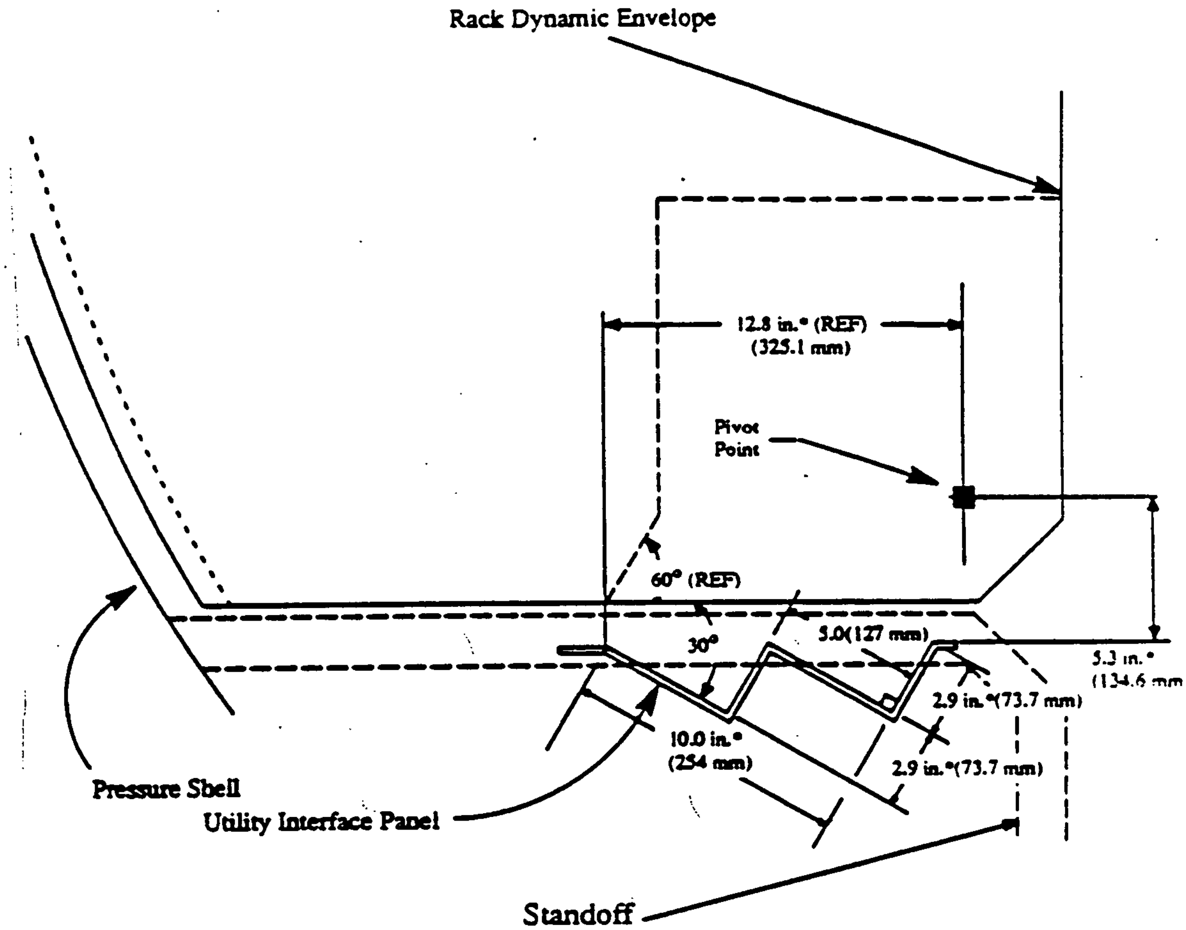


Figure 3.2-1 Space Station Utility Panel Location

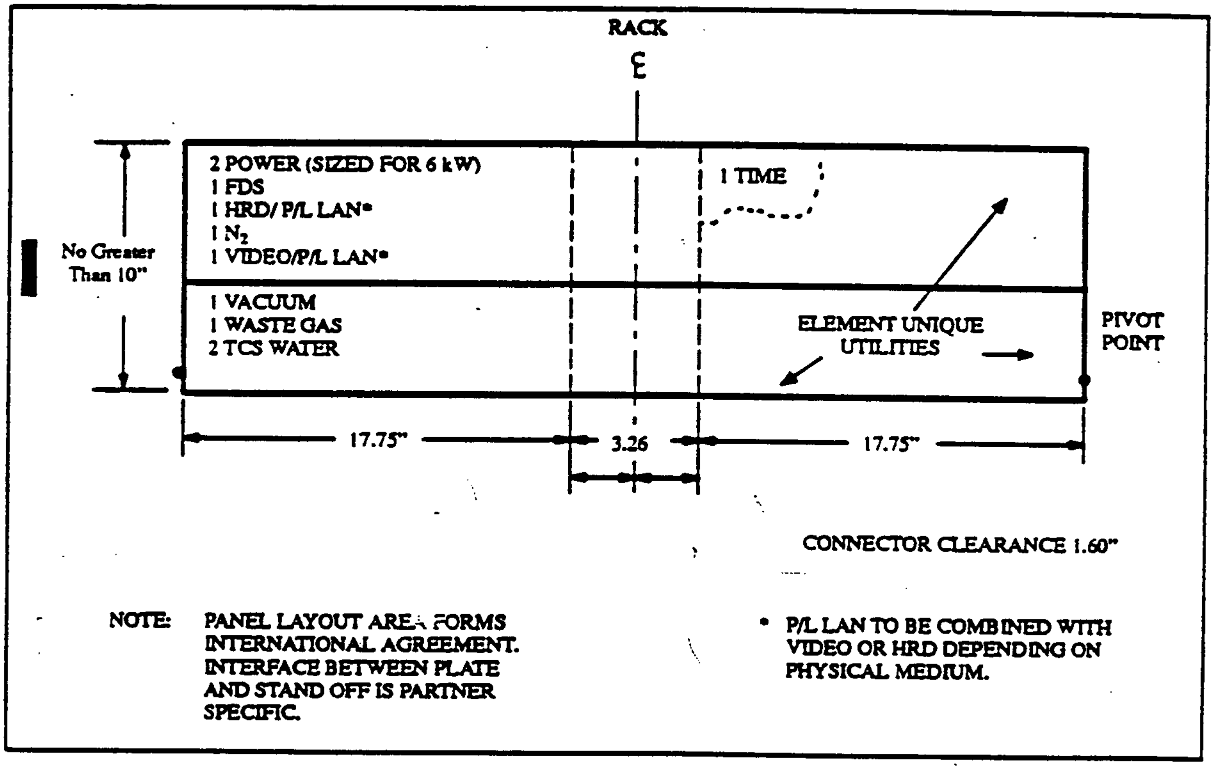


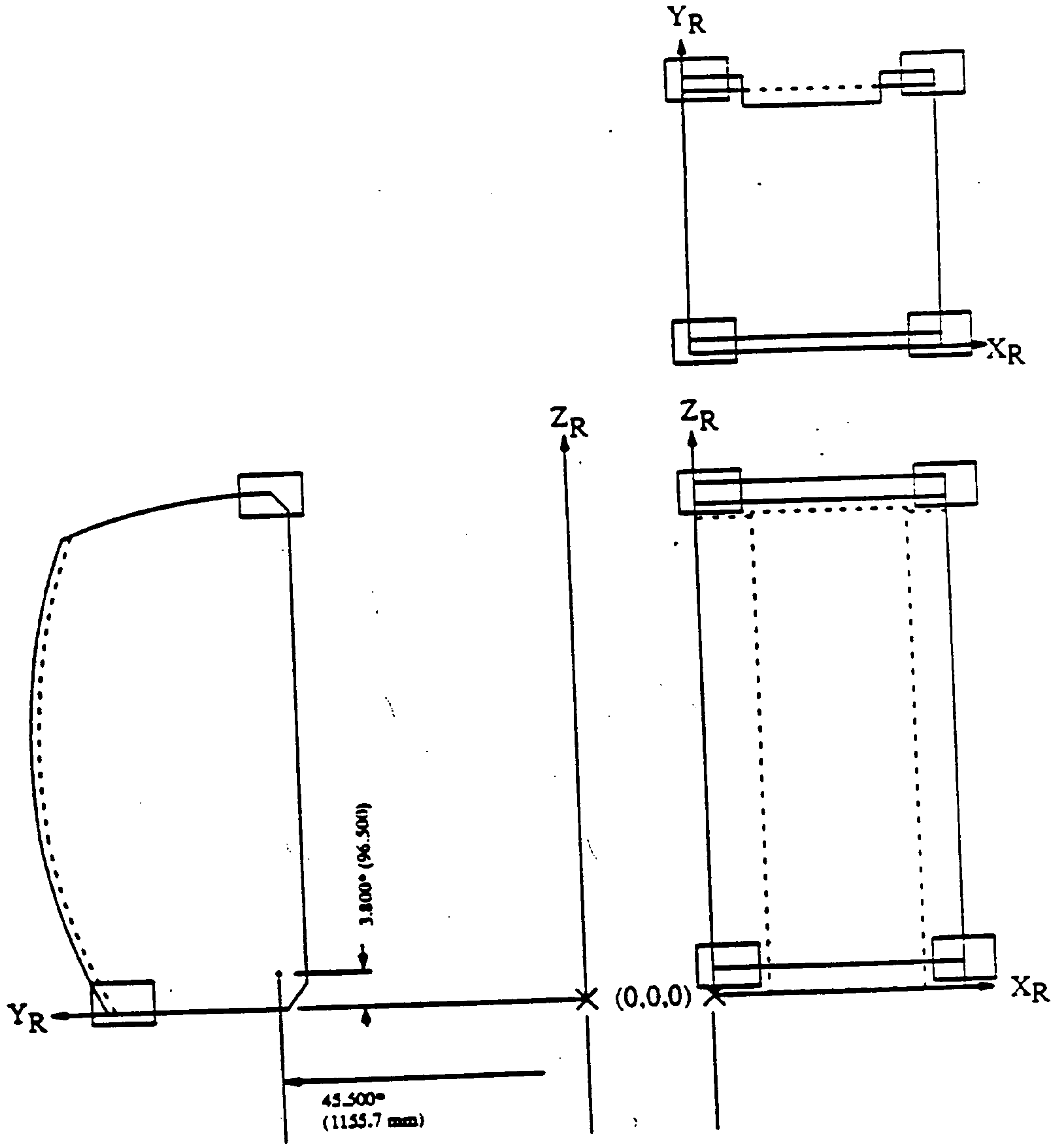
Figure 3.2-2 Space Station Utility Panel Layout

3.3 SSF Structural Interface Requirements

Structural interface requirements for the SSFF payload rack complement were taken from SSP 41002, Draft 12. Figure 3.3-1 depicts the required rack rotation axis and latch locations. For the SSFF rack interconnect definition study, structural hard point locations were not an issue. The rack interconnect simulator developed in this study accurately models the position of the rotation axis and the lower portion of the three SSFF racks. The principal design issue addressed with respect to the mechanical attachment locations was accurate modeling of the rotation axis and kinematics. Accurate rack model geometry assures that interconnect component locations and behavior during rack tiltout and return are representative of on-orbit behavior in the station.

A principal structural issue in developing the rack interconnect design for the SSFF was maintaining the ability to rotate the racks out for behind-rack access. The lower structure of SSF standard racks is continuous along the floor interface. Any interconnect lines in this area would interfere with rack structure during a single rack tilt-out. This ruled out above-floor interconnect routing for standard SSF racks, while below-floor routing was precluded by SSF restrictions, and access for on-orbit changeout.

At the same time that the finding was made that SSF standard racks would not permit rack-to-rack cabling, other portions of the SSFF study team determined that SSF standard racks could not support some of the identified SSFF payloads. Based on these findings and system requirements, the SSFF team developed a new rack concept design. This rack design is modelled in the SSFF rack interconnect demonstrator, and includes an open structure area at the front bottom of each rack, reserved for inter-rack cabling and plumbing. The open structure feature permits rotation of any SSFF rack independently of the others. As installed in the demonstrator, service loops are adequate to permit rack rotation without any manipulation or disconnection of inter-rack services.



Notes:

(1) Dimensions provided are the distance from their respective plane in the X_R, Y_R, Z_R coordinate system or their radius length in the case of radii.

(2) All dimensions are in inches followed by their metric equivalent.

Figure 3.3-1 Space Station Rack Pivot and Hard Point Locations

3.4 Services Interface Requirements

The SSFF Core facility will support attached experiments through a defined set of service interfaces. Since no Interface Control Document (ICD) was available for the SSFF, a study was performed to determine the anticipated service interface requirements. These services fall into three broad categories:

1. Electrical power, both conditioned and unconditioned;
2. Signal interfaces, analog and digital;
3. Thermal/fluids interfaces, including ECS coolant, purge gas, and vacuum vent services.

In addition to the services which are necessary to operate the materials processing payloads, there are other services which may be desired or required. The SSF Fire Detection and Suppression (FDS) may be required for all payload racks, for example, and some experiments may requires access the video service. The rack interconnect system should provide payload access to these services, in addition to the basic services required for experiment operation. Table 3.4-1 summarizes the initial list of identified electrical and fluid interfaces between the SSFF and the SSF.

Table 3.4-1, SSF Service Connection Summary

SSF Service	Number of Cables or Fluid Lines
Primary Power	1
FDDI	1
Video	1
Timing Data	1
Gaseous Nitrogen	1
Vacuum Vent Resource	1
Coolant	2
Fire Detection/Suppression	1

Once a practical layout had been established for the core facility rack, attention was turned to the interconnect architecture at the furnace experiment stations. Review of the design requirements disclosed that larger experiments, such as the CGF, may occupy the volume reserved in standard space station racks for connector panels. Based on this finding, the rack interconnect design futher evolved, splitting the interconnect panels at the experiments into two smaller panels, located on either side of an experiment apparatus container. This configuration is shown in Figure 3.4-1, and resolves conflicts between experiment services requirements and the volume limitations and maintainability requirements imposed on the furnace facility design team.

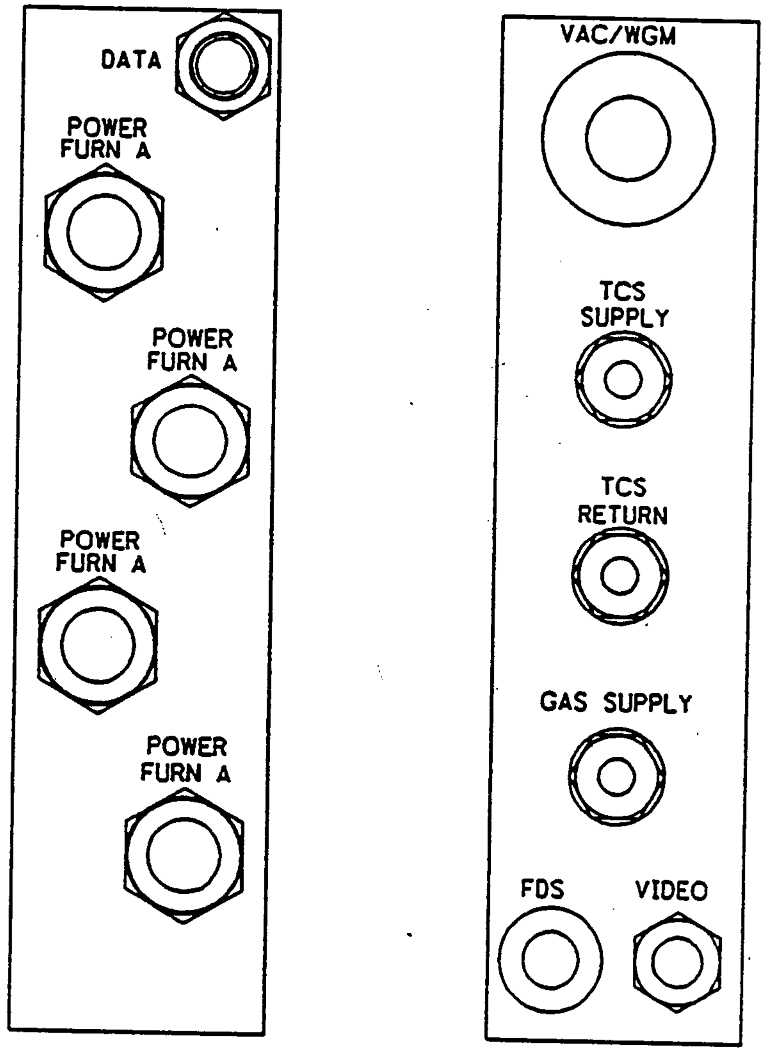


Figure 3.4-1 SSFF Experiment Rack Connector Panel Layout

In addition to the evolution in the connector panels for SSFF interfaces, a study was performed to develop a design for placing interconnection cables and lines between racks without interfering with single-rack tiltout. Early in this study it became apparent that the interconnect cabling was incompatible with the combination of standard SSF racks and the requirement for single rack tilt-out. At the same time, work on the SSFF demonstration article established that interface requirements between the core and experiment racks would preclude use of the standard SSF rack for the furnace facility.

In developing SSFF system interconnect requirements, the CGF and Programmable Multi-Zone Furnace (PMZF) payloads were used as baseline requirements drivers. The CGF is a large and heavily instrumented payload, and thus places demands on data and control interconnections. The multiple independently controlled heater zones in the PMZF required a large number of separate heater power and temperature sensor connections. As flown on the Spacelab, the CGF required close to one hundred signal pairs for telemetry/control and a dozen circuits for power transfer to the furnace assembly. It also has extensive ECS and vent/purge plumbing. Initial SSFF rack interconnect layouts were drawn to accommodate the entire CGF interconnect complement, plus providing adequate power cabling to support PMZF requirements. The initial interconnect design also provided for access to space station services which are not utilized in the CGF/Spacelab installation. These extra SSF interfaces included high purity water, station-supplied inert pressurant (nitrogen), and video services.

3.5 Rack Tilt-Out and Access Requirements

In addition to providing hoses and cables to convey SSF services to the furnace facility experiments, the rack interconnect system must permit tilt-out of any of the SSFF racks. Tilt-out is required for service access to rack-mounted equipment, and for contingency access to the pressure hull area behind each rack. The design driver for the system was a requirement that rack tiltout should be possible without disconnecting any of the rack services to prevent any furnace damage. A specific SSF objective applied to all rack-mounted payloads requires that the rack must be capable of rotating approximately ninety degrees within sixty seconds. Crew-applied forces to accomplish the tilt-out should not exceed established human factors limits for crew members.

Analysis was performed to predict the force profiles required to accomplish the required rack tilt-out and re-stow. In order to provide an adequate safety margin, thirty seconds was chosen for the analysis and design. Tiltout forces which must be overcome by the crew come from three separate sources. First is the mechanical friction in the rack rotation bearings. Since these bearings will be essentially unloaded on orbit, these frictional forces should be rather small, and were therefore neglected. The remaining resistive loads are those due to the interconnect system stiffness and hysteresis, and the inertial loads induced as the racks are rotated.

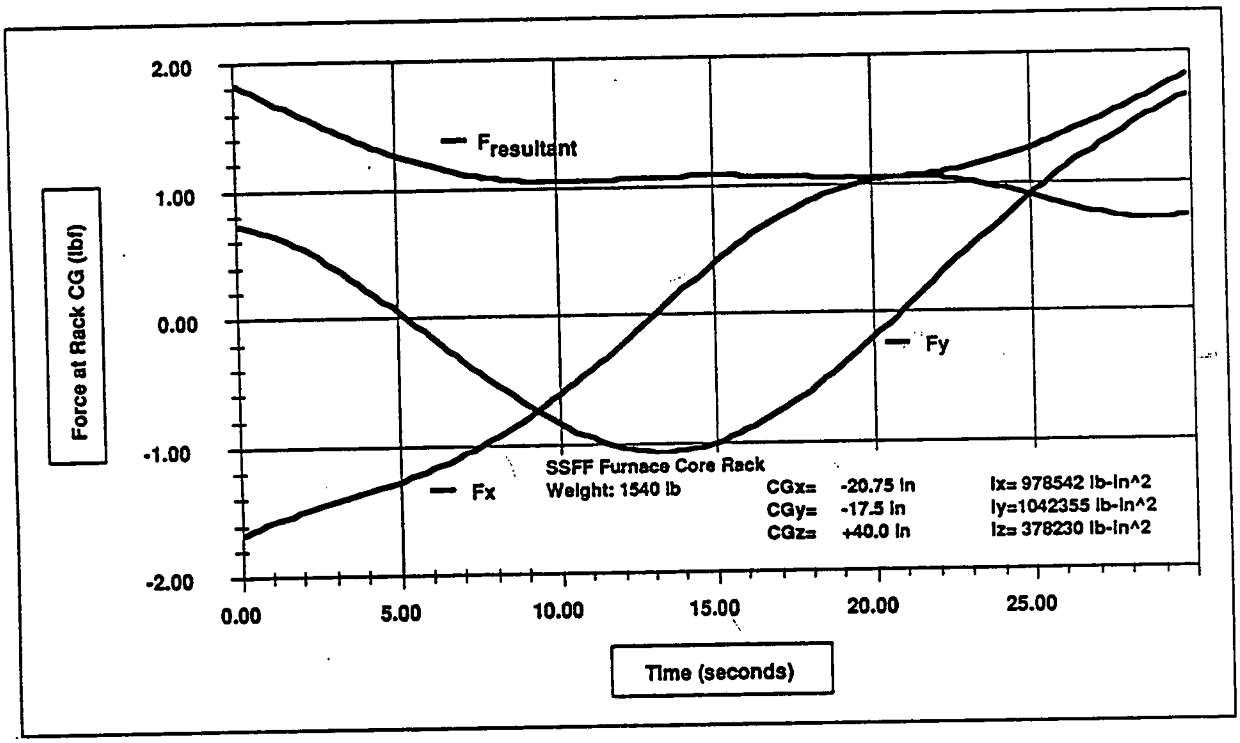
In this study, rack inertial loads were calculated by analysis, based on the kinematics of the rack rotation and assumed mass properties of the payload and core racks. Table 3.5-1 shows the mass and CG assumptions made in this analysis. Figure 3.5-1 shows the forces required at the core rack to overcome inertial effects during tiltout, and Figure 3.5-2 shows the tiltout sequence. Due to the relatively long time (30 seconds) allowed for tiltout, inertial forces are

low, never exceeding two pounds. Details of the kinematic analysis may be found in Appendix D.

Table 3.5-1 SSFF Mass Properties Used in Kinematic Analysis

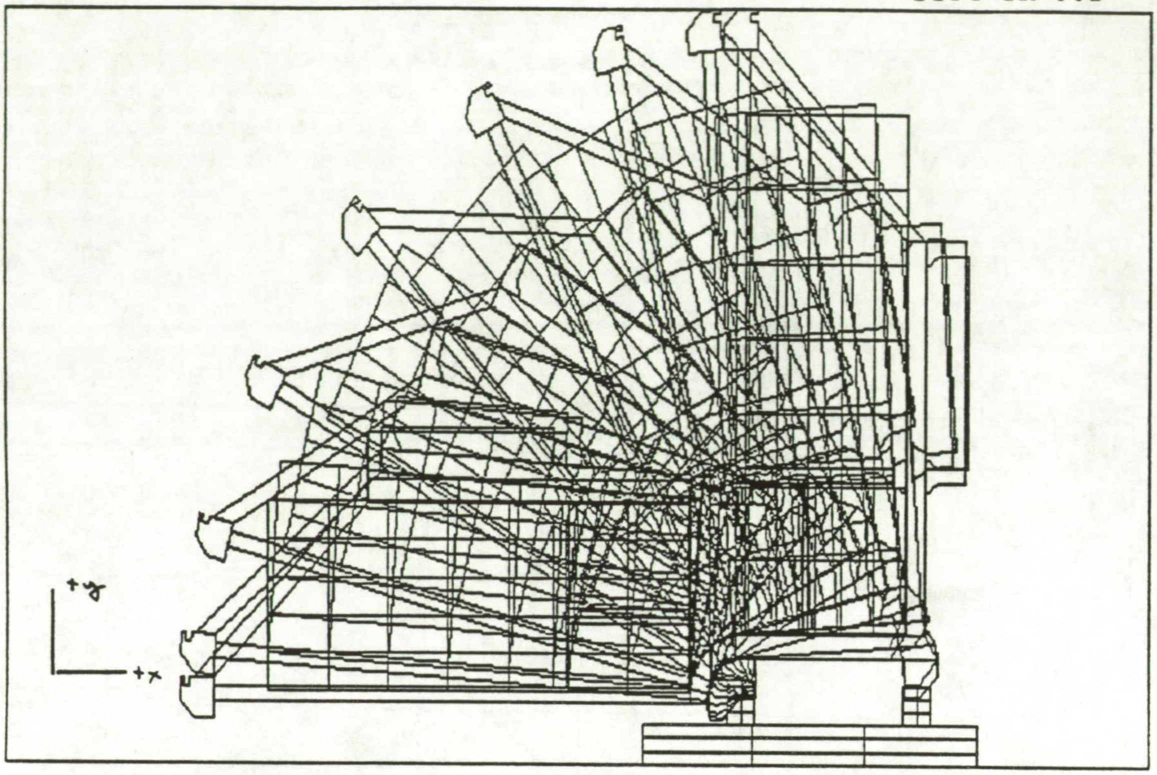
SSFF Furnace Support Structure Rack (including CGF)		
Weight: 1150 lb	CGx= -20.75 in CGy= -17.5 in CGz= +24.0 in	Ix=730729 lb-in^2 Iy=778382 lb-in^2 Iz=282444 lb-in^2
SSFF Furnace Core Rack		
Weight: 1540 lb	CGx= -20.75 in CGy= -17.5 in CGz= +40.0 in	Ix= 978542 lb-in^2 Iy=1042355 lb-in^2 Iz= 378230 lb-in^2

The interconnect (cable and hose) stiffness was determined by physical modeling and test of the interconnect system. Mockups of the SSFF rack bases were fabricated, and complete interconnect systems installed. The rack bases were counter-balanced to minimize forces due to gravity. Tests were run with the hoses both pressurized and unpressurized, to determine whether the operational condition of the fluid systems had a significant affect on the tilt-out forces. The maximum moment applied to any SSFF rack at any point in tilt-out was found to be less than 150 inch pounds, equivalent to a three to four pound force applied at the upper rack structure. These results, including measured torque data may be found in Section 5.2.. Details of the rack model and tilt-out tests may be found in Appendix A.



CORE RACK TILT-OUT FORCES
(Due to Inertial Effects)

Figure 3.5-1 SSFF Inertial Force Time History for Rack Rotation



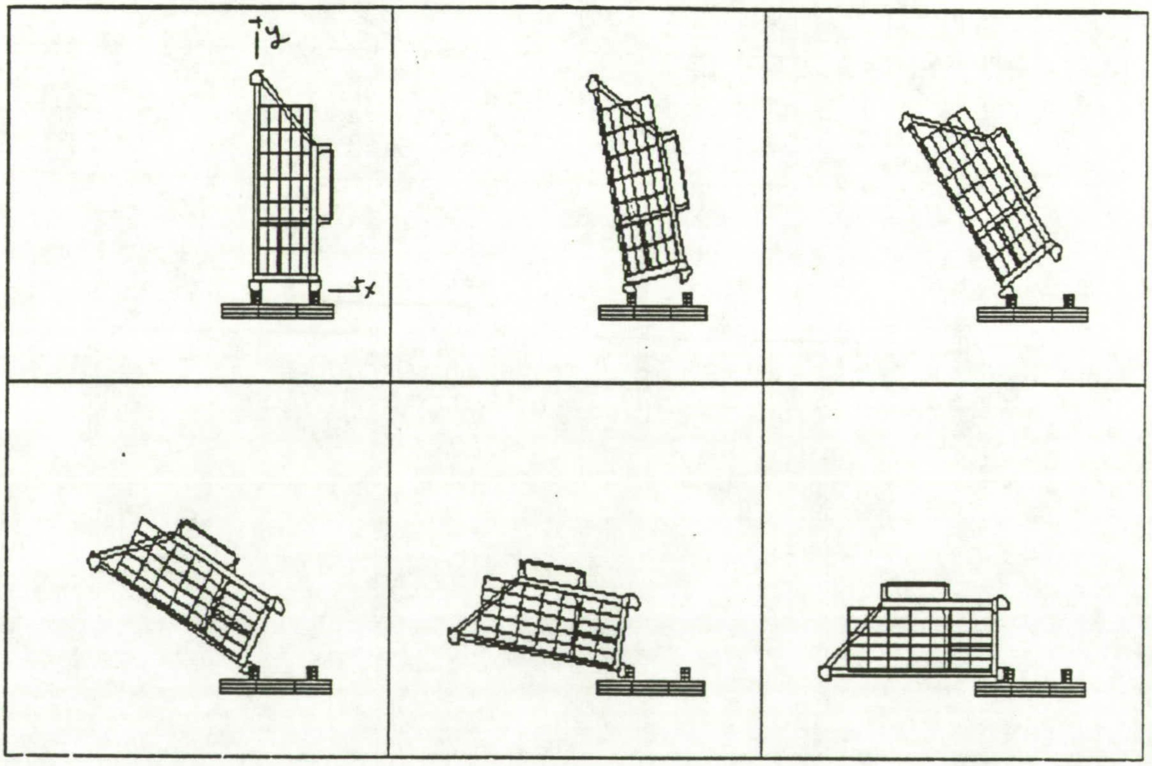


Figure 3.5-2 SSFF Rack Rotation Sequence

4.0 RACK INTERCONNECT SYSTEM CONFIGURATION

The rack interconnect system provides all necessary services for the SSFF. Interconnect features were standardized to model SSFF experiment developers defined interfaces with the core facility for electrical power and signals, ECS fluids, and pressurants.

4.1 SSF Services

The SSFF obtains services from the SSF through the ISPR panel and an interface panel located at the base of the rack, as shown previously in Figure 3.2-1 and 3.2-2.

4.2 Electrical Power/Data Services

The SSFF will supply conditioned power to the experiments through the rack interconnect cabling and connectors. The rack interconnect demonstrator provides for up to 32 separately controlled furnace heaters, along with unconditioned power to operate the experiment systems. Command/control and telemetry data are transferred through a signal cable between each experiment and the core rack. Experiment power is delivered from the core rack through twelve gauge cables, and prime power to the core rack is accepted through four gauge cable sets. Figure 4.2-1 is a block diagram of the SSFF electrical interconnect service system.

All of the rack model electrical connectors are MS 24473, MS 3474 and MS 3476 types, identical to current usage on Spacelab experiments. M 27500 and 22759 wire types were used for cable assemblies, with construction similar to current Spacelab experiment practice. Cable assemblies are contained in flexible conduit, the only major design change from previously flown hardware. The flexible conduit design provides electrical shielding to the cable bundles and protects the cabling from abrasion and puncture hazards during rack tilt-out. The conduit-contained cable bundles do not have to be laced at intervals, as would be required for open cables, which results in lower cable bending stiffness and in smaller permissible bend radii.

4.3 Thermal Conditioning System

The rack interconnect demonstrator provides water coolant lines capable of delivering sufficient coolant to the two experiments. These lines are three-eighths-inch flexible hoses, with teflon liners and stainless steel overbraid. Thermal Control System (TCS) hoses on the demonstrator terminate in form-only models of the proposed interconnect quick disconnects. Functional quick disconnect fittings are available and were selected but not used in the demonstrator due to high cost and long lead times to delivery. The quick disconnects modeled are capable of 2,000 psia working pressure, and when disconnected close off both male and female ends without leakage. This design will permit on-orbit replacement of hoses without zero-g cleanup of working fluids. Figure 4.3-1 is a block diagram of the SSFF Fluid Interconnect system.

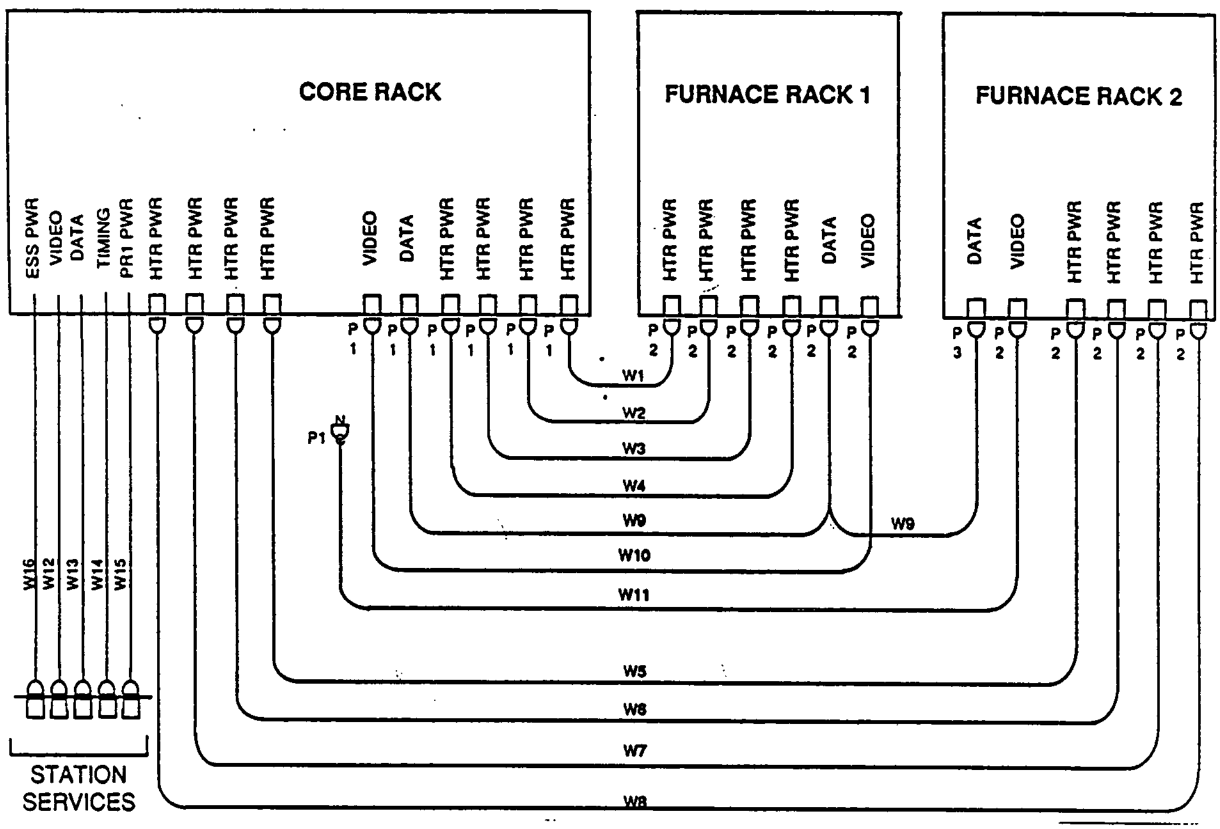


Figure 4.2-1 Block Diagram of SSFF Electrical Interfaces

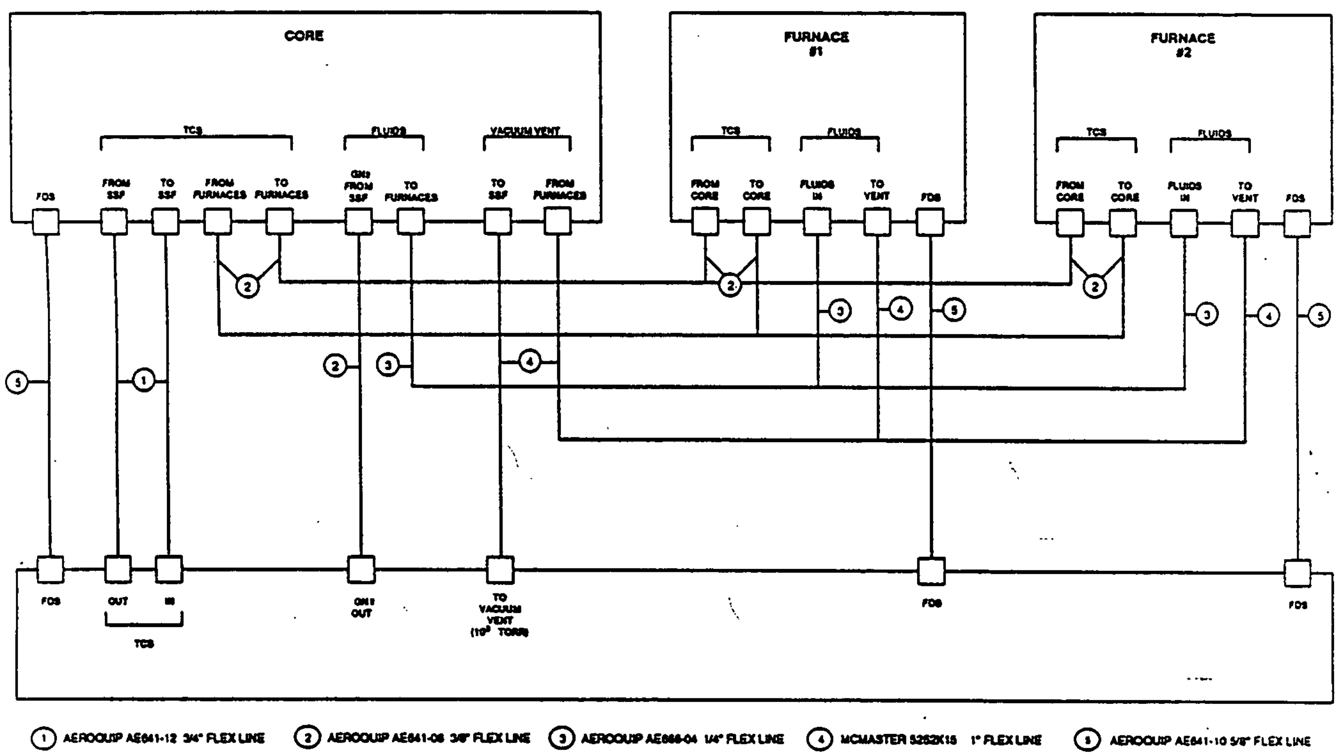


Figure 4.3-1 SSFF Fluid Interconnect System

4.4 Pressurant/Vent System

One-quarter-inch flexible hoses, with teflon liners and stainless steel overbraid are used for the pressurant (Argon) supply hoses, and one inch hoses make up the vacuum vent interconnect. Due to limited bend radius of the one-inch size hoses, some rigid fittings are used in the vacuum vent interconnects. The pressurant/vent system also uses double-ended-shutoff quick disconnects similar to those installed in the coolant system.

5.0 DEMONSTRATION TEST ARTICLE

A demonstration test article was constructed to determine whether the proposed interconnect architecture could function within the confines of a SSF module installation. The test article was used to verify cable and hose routing, access to connectors, panel layout, and operating forces.

5.1 Physical Description

The test article models the lower one-third of the core facility and two racks. Only the lower portion of the racks was modeled in detail, since the upper portions are not affected by the interconnect design. SSF ISPR interface plate position and rack pivot points are precisely modelled. Figure 5.1-1 shows a representation of the test article assembly which illustrates the interconnections in the SSFF concept model.

Counterbalances were installed on the core rack and one experiment rack to permit measurement of forces due to cable and hose flexure separate from mass loading of the interconnects. These balance weights placed the center of gravity of the test article near the rack rotation axis when the racks were in the normal operational position. Cable and hose flexure cause a change in the CG location during tilt-out, so that the counterbalance becomes less effective as the racks are rotated out.

5.2 Test Results

Figure 5.2-1 summarizes the torques measured during testing of the rack interconnect demonstrator. The highest torque recorded for either tested rack was less than two hundred fifty inch-pounds. This translates to approximately a five pound force applied at a rack handle located fifty inches from the rotation axis. The test overstates on-orbit torques due to two effects. First, the loss of counterbalance accuracy during tiltout resulted in unrealistic gravity loads. Second, measured torques include bearing friction due to the weight of the payload on the rack pivots. Even though the measured torques exceed expected on-orbit values, no human factors force limits were violated during any rack tiltout operation. The conclusion from testing is that the rack interconnect design presented is suitable for use on the space station from a human factors standpoint.

All connectors were found to be accessible for service change-out, and cables and hoses could be removed from the system without difficulty. With the single exception of the vent hose, all interconnect components had acceptable bend radii at any rack position. A complete test report may be found in Appendix A.

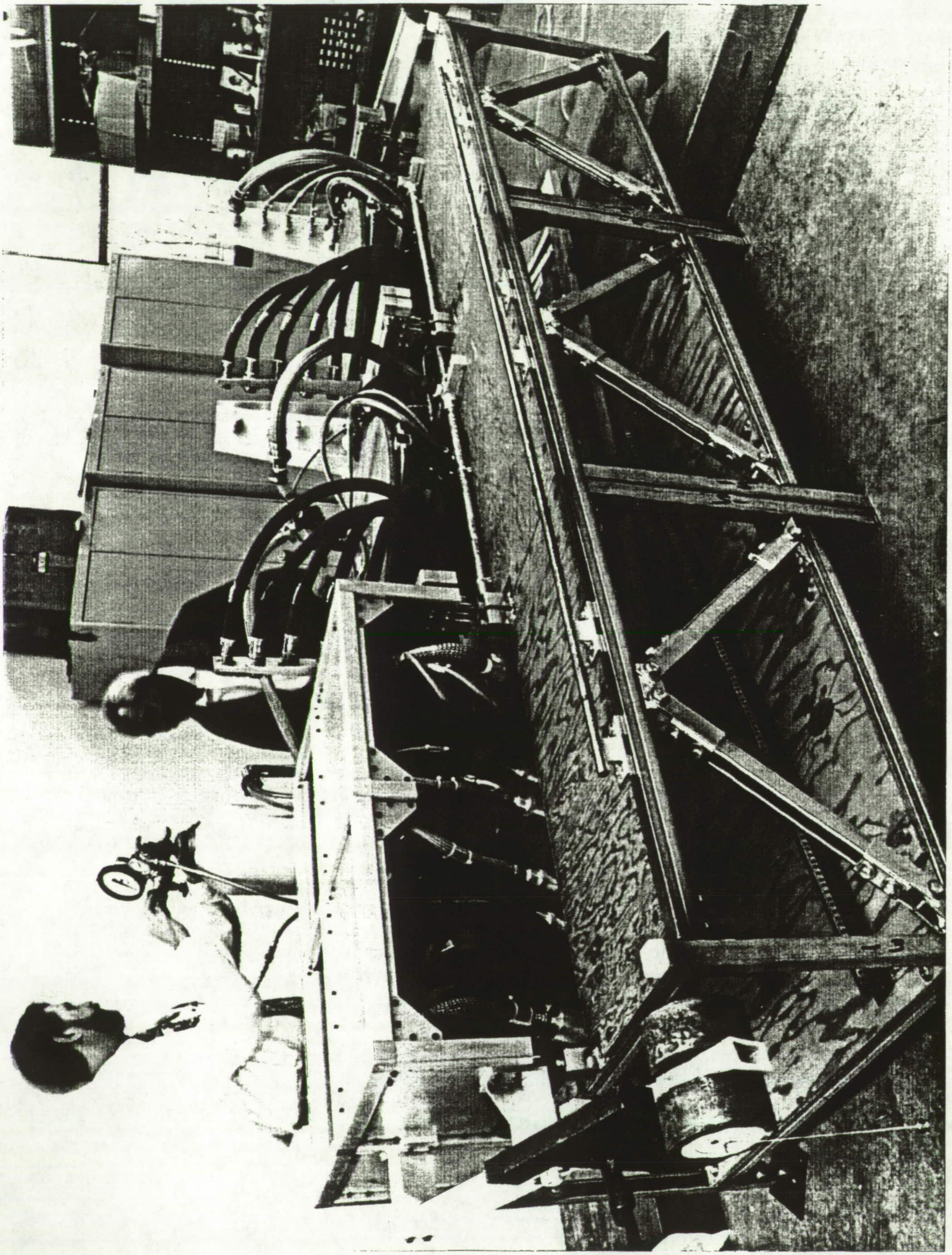


Figure 5.1-1 SSFF Rack Interconnect Test Article

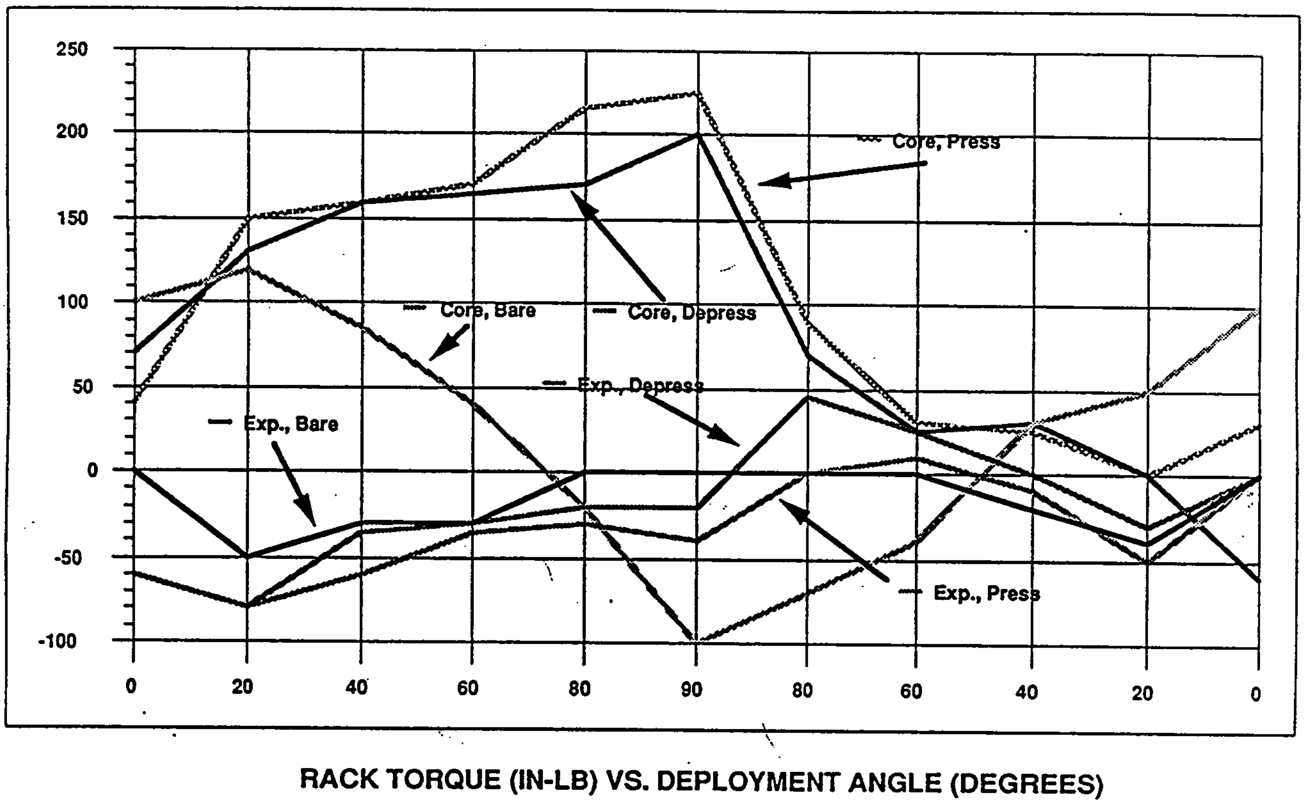


Figure 5.2-1 SSFF Measured Rack Rotation

6.0 CONCLUSIONS

The design developed for SSFF interconnection systems is feasible and represent low development risk for the program. No exceptions need be taken to any SSFF or SSF technical requirements to incorporate the design modeled in the SSFF rack interconnect demonstration unit.

6.1 SSFF Interconnect Architecture

The SSFF inter-rack connection system as designed for this study requires the use of SSFF specific experiment racks. The SSFF specific experiment racks are designed to permit rack tilt-out with the inter-rack cabling and fluid connections in place, as well as to accept full-size furnace payloads. The SSFF interconnect system uses flight-proven hardware designs for electrical wiring and connectors and fluid connections. The electrical cables will be housed in flexible conduit, a low-risk improvement over established design. The fluid systems connectors selected in this study are used in other flight systems, but would need qualification for use in the SSF.

Interconnections provided by the SSFF terminate at the experiment interface panels. From here, the SSFF services are provided to the experiment and distributed core equipment through experiment-peculiar cables and hoses. This architecture provides experimenters with a well defined physical interface, and would permit experiment change-out on orbit with minimum modification to the core facility and no modification to the interconnect system. between the core facility and the experiments

6.2 Fluid Systems

The rack interconnect fluid lines selected in this study are standard flight hardware design, with teflon liners and stainless steel overbraid. The quick disconnects selected provide very little pressure drop when connected, and a leak-free shutoff when disconnected. This design will allow SSFF experiments to be integrated with a full coolant load, avoiding mixed flow or on-orbit purging of the payload coolant circuit. The vacuum vent lines were sized at one inch, a compromise between throughput capability and bend radius limits. Rigid lines were used in a portion of the vacuum vent interconnect to improve venting throughput. All other lines in the system are flexible and may be easily replaced on-orbit. All of the fluid system components selected and used in the demonstration unit are expected to have service lives compatible with SSF requirements. On-orbit replacement of fluid system components should be required only when there is to inadvertent physical damage or system contamination.

6.3 Electrical Interconnect Design

The SSFF interconnect system as configured in the interconnect system demonstrator is a usable and compliant design. The flexible conduits used to protect electrical cables are light and flexible. Since the cable bundles within the conduits are not laced, cable flexibility is enhanced. The segregation of signal and power cables in separate conduits appears to be a practical method for managing the design to avoid EMI/EMC problems, and can be implemented easily. Since the interconnect cables all have connectors at both ends, any cable may be replaced on-orbit without tools. All electrical cables are point-to-point, i.e. no cables have more than two connectors. This design permits changeout of isolated portions of the connection system without affecting any other cables. This feature might be of value if, for example, an upgrade to the SSFF adds advanced technology connections after the initial on-orbit integration.

The electrical cables, as installed on the demonstration unit, are compliant with all identified electrical performance requirements, and permit rack tiltout without any disruption of SSFF services. The flexible conduits used have not been qualified for the SSF application, and materials qualification will be required before these are incorporated into the flight hardware design. This materials compatibility qualification is felt to be a low risk process, and it is recommended that these conduits be used in the flight design.

APPENDIX A

TEST PROCEDURE AND RESULTS

APPENDIX B

RACK INTERCONNECT DEMONSTRATION UNIT DRAWINGS

APPENDIX C

RACK TILT-OUT KINEMATIC ANALYSIS SUMMARY

APPENDIX D

TRADE STUDY SUMMARY MEMOS

DEVELOPMENT PLAN

FOR THE

SPACE STATION FURNACE FACILITY DEVELOPMENT MODEL

February 1991
Space Systems Division
Teledyne Brown Engineering

FORWARD

This document has been prepared as part of the Development Model effort on Contract NAS8-38077 for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, by Teledyne Brown Engineering.

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1.0 INTRODUCTION

The Space Station Furnace Facility (SSFF) is a micro-gravity materials processing experiment facility. It is scheduled for installation and operation in the United States Laboratory (USL) Module of the Space Station Freedom (SSF). It is designed for micro-gravity materials research in metals, oxides, glasses, and alloy solidification and crystal growth of electronic and electro-optical materials.

Micro-gravity materials processing is an important area of research interest for potential advances in materials, crystal growth science and materials production. Reduction of gravity flows in the processing of metals, glasses and alloys has the potential to result in formation of materials with unique or improved properties. It will also result in a better understanding of the various solidification phenomena involved. Crystal growth in a micro-gravity environment is important because it should result in higher quality crystals required for advanced electronic and electro-optical devices.

The SSFF consists of a Core Facility and two furnace modules. A block diagram representation is shown in Figure 1.0-1. The Core facility interfaces with the Station provided services, converts these services for use with the furnaces, and provides the services to the furnace modules. The Core also provides central operational control and data acquisition for the furnaces.

The overall program plan for the SSFF consists of three phases. Phase A consists of the conceptual design and requirements definition. Phase B consists of the refining of the requirements and concepts, and the construction of a development model to demonstrate feasibility. Phase C/D consists of the design, construction and testing of the flight SSFF systems.

The SSFF Development Model is a part of the current Phase B contractual effort. This Model is designed to demonstrate the feasibility of the SSFF concept. It models the functions and physical interfaces of the SSFF including the Space Station services and the furnace modules. Additionally, the development process itself will help identify issues and solve problems related to specification, design, construction and operation of the SSFF in the Space Station environment.

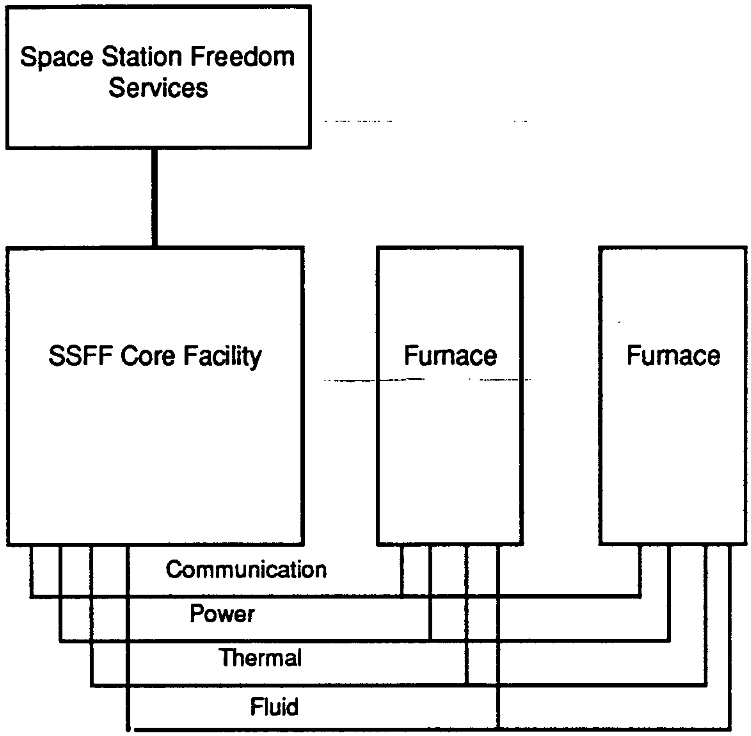

FIGURE 1.0-1 SPACE STATION FURNACE FACILITY CONCEPT

This SSFF Development Model Development Plan describes the plans, activities, and approaches for the design, construction and test of a high fidelity SSFF operational model. It also serves as the concept description and system requirements document.

1.1 BACKGROUND

A brief review of the background of the steps leading to this development plan is presented below. This provides some history in the evolution of the concept and gives an idea of the basis and scope of the development model effort.

The initial SSFF study phase (Phase A) was begun in 1989. The purpose of this study phase as stated in the SSFF contract was to provide "...the preliminary definition, analyses, and assessment of requirements; conceptual design of the SSFF; fabrication of mockups; and the preparation for and support of the Conceptual Design Review."

The Conceptual Design Review (CoDR) was held in August 1990. The documentation package for this review contained a draft of the Development Model Development Plan with the approach that was defined at that time. The package also contained several reports describing the concepts and requirements for the SSFF and its subsystem parts. This package and the comments received from the CoDR board members provided the basis for the SSFF concept itself and the concept for the Development Model.

In general the CoDR board comments were favorable, the efforts were approved, and authorization to proceed to the next phase (Phase B) was granted. One significant comment from the CoDR board was that the Development Model should minimize simulations of the operations and equipment, and include actual or high fidelity hardware models. It was also noted that the Development Model should operate with an actual furnace if a furnace was available to provide the most realistic demonstration of concept feasibility. The model concepts and design was therefore modified to meet these directions.

Phase B began in January 1991 and is ongoing. The purpose of this phase as stated in the SSFF contract is to "...cover the updating of requirements and documentation; refining the conceptual design based on CoDR inputs; preparation for and support of the Requirements Definition Review; and the design, construction, and testing of a development model to demonstrate design feasibility.

Another significant event that around January 1991 was the restructuring of the Space Station based on congressional direction to produce a less costly design. Results of the restructuring activities were due to be published in February 1991.

A Draft Development Plan was begun in January. But, with the Space Station restructuring activities in process it was felt that the completion of the Plan should be delayed until the restructuring could be incorporated. Then, although the major restructuring results were published in February, details important to the Development Model design were delayed. In fact, several of the Station interfaces and services are still going through changes. Details were published in various forms from March to May. These details have been incorporated into the design.

For these reasons, it was decided that the original Draft plan should be published as a historical document to show the plan at the beginning of Phase B, and that a new development plan be developed to show the plan for the Development Model based on the CoDR concept and the restructuring impacts.

This Development Model Development Plan provides the development planning for the design, construction and test of the SSFF Development Model. It presents the concepts and approaches for the Development Model based on the CoDR concept with the changes due to Station restructuring as of the beginning of June 1991. It provides the requirements definition and preliminary design of the Development Model that specifies the detail design, construction and test.

1.2 OBJECTIVES

The main objectives of the SSFF Development Model are stated in the contract Statement of Work:

Contract SOW Paragraph - 5.3 Development Model Design, Fabrication, Assembly and Test

"The contractor shall design, fabricate, assemble, and test a development model of the core facility to demonstrate the feasibility of the design concept selected. The development model shall be designed to provide high-fidelity physical and functional interfaces with the experiment modules and Space Station interfaces to the extent that they are defined. Commercial grade parts and equipment will be acceptable for control and data acquisition systems, thermal control and other support systems. The development model shall be designed so that it can be configured to operate each type of furnace for selected '"strawman" experiments. Operation of all types of furnaces in parallel is not required; however, parallel operation of the furnace modules in the USL shall be considered and the core facility development model shall be used to demonstrate this capability. Demonstration tests shall be conducted to demonstrate operations in the man-tended and fully manned modes."

An overview of how the plan for the Development Model will meet these objectives is given below. More detail is contained in subsequent sections of the plan. Objectives extracted from the SOW are listed separately and discussed.

1) "...demonstrate the feasibility of the design concept selected."

The Development Model will provide a Core Facility, two furnace models, and a model of the Space Station services. A block diagram of the configuration is shown in Figure 1.0-2. The design, as presented in this Development Plan, is based on the SSFF CoDR concept and the changes incorporated due to Station restructuring. The Development Model design allows for flexibility in configuration after the base configuration design is completed and tested. This allows incorporation of refined concepts. The CORE is designed to provide centralized services common to two furnace models. These were chosen to be two Crystal Growth Furnace (CGF) furnace models since there was sufficient data available to model them. The CORE design provides required services and allows for reconfiguration for operation with an actual furnace if one should be made available. Additional objectives of the Development Model include the following: (a) formation of a design team to develop the model with an integrated approach so that design issues are addressed from a

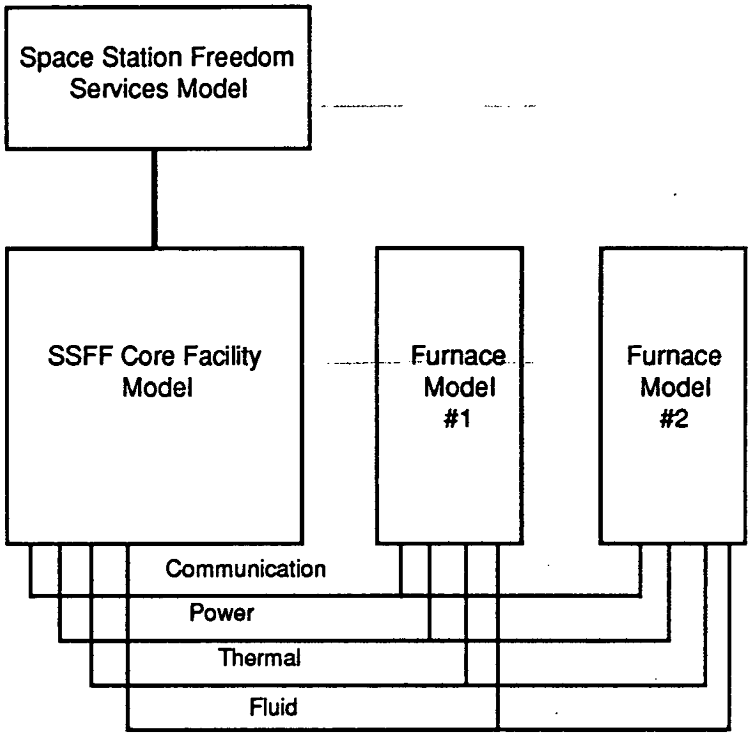

FIGURE 1.0-2 SSFF Development Model Concept

system standpoint and trade decisions are made by the team; (b) communication of information from the Development Model design team to the conceptual designers to aid in the establishment of requirements and specifications for the flight SSFF; and (c) performance testing of alternate approaches to not only show feasibility, but to also compare feasible approaches.

2) "...provide high-fidelity physical and functional interfaces with the experiment modules and Space Station interfaces to the extent that they are defined."

The Development Model design provides high fidelity physical and functional interfaces. However, the Space Station interfaces have been undergoing changes so frequently that it has not been possible to completely define them. Therefore the Model is designed using interfaces that match the definitions available. As these interfaces reach maturity, the Model may be reconfigured to match them. The experiment module interfaces are well known since CGF was chosen as the furnace model. These interfaces provide a high-fidelity model both functionally and physically.

3) "...designed so that it can be configured to operate each type of furnace for selected 'strawman' experiments."

The development Model is designed to be reconfigurable for several types of furnaces. Data from several furnace types were reviewed for service requirements. Detailed data was available only for CGF. Some data was available for the Programmable Multi-Zone Furnace (PMZF) and was used in the design. Additionally, data from an in-house research project, the Transparent Furnace, was used in the design. Analysis of this data indicated that a hardware design that provided services to CGF and PMZF would accommodate other furnaces. The Development Model software is also designed to be capable of reconfiguration for operation of other furnace types.

4) "...parallel operation of the furnace modules in the USL shall be considered and the core facility development model shall be used to demonstrate this capability"

The Plan includes demonstration testing to meet these objectives. The definition of these tests will be documented in a separate Demonstration Test Plan. Operation of the SSFF Development Model will be demonstrated using two CGF furnace models. The furnaces will be operated at the same time using typical operation timelines defined for the demonstration. The operational scenario will include functions designed to demonstrate operations aboard the Station. This is planned to include staggered timeline operation to meet power constraints, as well as other scenarios.

5) "Demonstration tests shall be conducted to demonstrate operations in the man-tended and fully manned modes."

The Plan includes demonstration testing to meet these objectives. The definition of these tests will be documented in a separate Demonstration Test Plan. The operational scenarios will be defined to include test conditions to demonstrate both man-tended and fully manned modes.

2.0 APPLICABLE DOCUMENTS

The following documents provide additional information and references which are applicable to the development model effort.

JA55-032	Space Station Furnace Facility Science Requirements Document
JSC-30000	Program Definition Requirements Document (PDRD) for the Space Station
NAS8-38077	Space Station Furnace Facility Research Study
SS-SPEC-0002	U.S. Laboratory Module Contract End Item Specification
SSP 41002	International Standard Payload Rack to NASA/ESA/ NASDA Modules Interface Control Document

3.0 DEVELOPMENT MODEL

3.1 OVERVIEW

The SSFF development model implements most functions of the SSFF concept. The functions implemented in the development model are categorized as SSFF Ground Support Services (GSS), SSF Services, SSFF Core Facility Services (CFS), and the SSFF Furnace Experiment Package (FEP). The major objective of the SSFF development model is to model the SSFF Core Facility Services. The GSS, SSF Services, and FEP(s) are modeled to the extent required to support operation and demonstration of the SSFF CFS model. Figure 3.0-1 depicts the overall concept of the development model.

The functions modeled for each category are defined in section 3.2 of this document. The design of the development model is defined in section 3.3 of this document.

3.2 FUNCTIONAL DESCRIPTION

3.2.1 Ground Support Services Model

The GSS model will provide the command and display services normally provided at a Payload Operations Control Center. It will also provide maintenance functions for the SSFF databases.

3.2.1.1 Command and Display - The Command and Display function will support both on-line and off-line activities of the SSFF CFS model. For on-line operations, this function will collect, process, display, and log data received from SSFF CFS model. It will also provide an operator interface to the SSFF CFS model through command shells. During off-line operations, the Command and Display function will provide the capability for post processing analysis of the logged data.

3.2.1.2 Database Maintenance - The Database Maintenance function will provide off-line activities for defining and converting the mission specific and sample specific databases needed by the SSFF CFS model. Specifically, it will provide the operator interface to create and maintain mission specific and sample specific databases. It will convert each database to a Dedicated Experiment Processor load file for transfer to the SSFF CFS model.

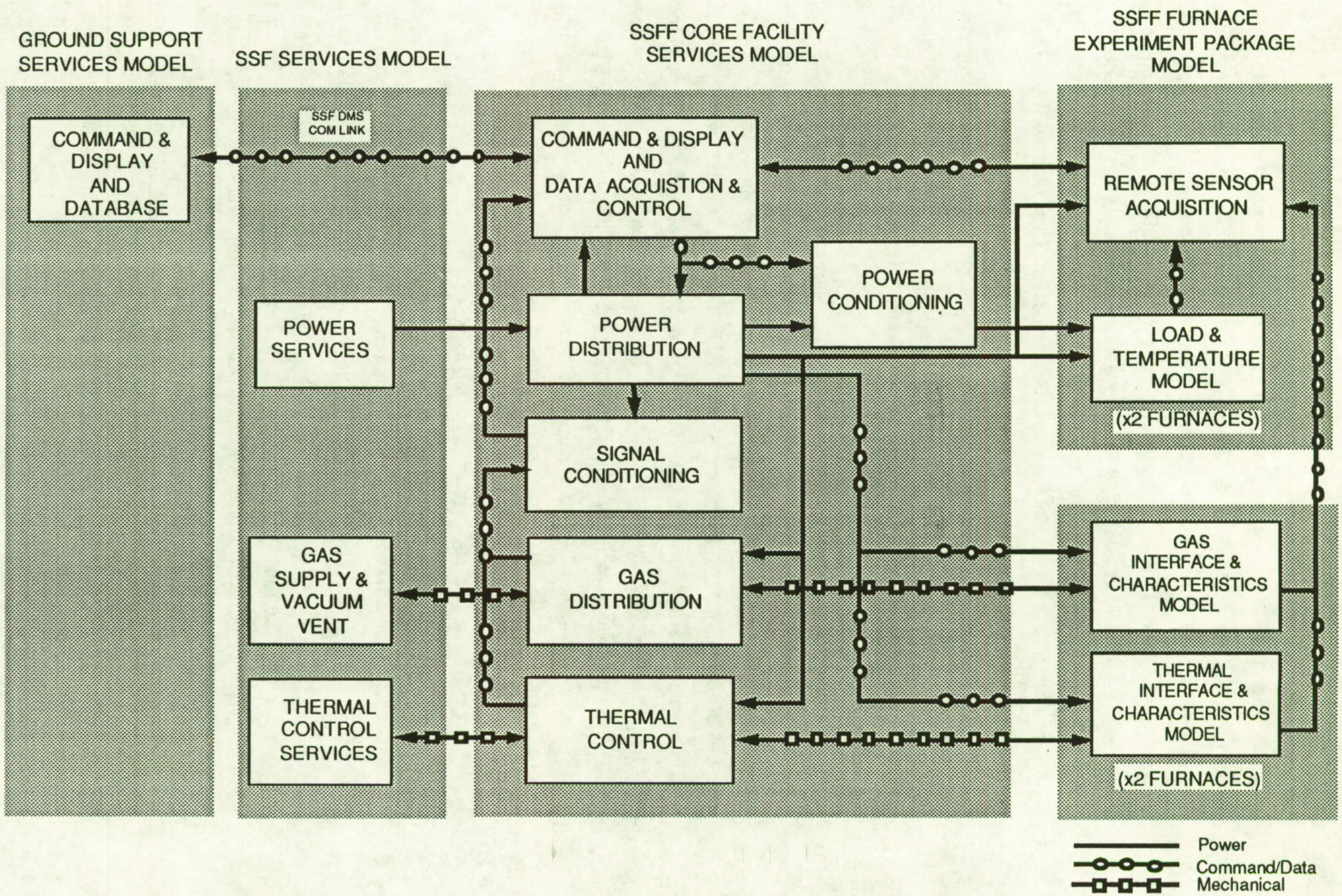

FIGURE 3.0-1 SSFF DEVELOPMENT MODEL FUNCTIONAL BLOCK DIAGRAM

3.2.2 SSF Services Model

The SSF Services model will perform four of the functions which are provided by the SSF and used by the SSFF: Data Management System communications link, power services, gas and vacuum services, and water services. These functions are described in the following paragraphs.

3.2.2.1 Data Management System Communications Link - The SSF Services model will provide the Data Management System communications link between the SSF CFS model and the GSS model. This link will be digital and bi-directional.

3.2.2.2 Power Services - The SSF Services model will provide the 120 Vdc power supplied by SSF to the extent required by the SSFF CFS model. The model will also provide all of the necessary circuit breaker panels and power cables.

3.2.2.3 Gas and Vacuum Services - The SSF Services model will provide an approximately 90 pounds per square inch (psi) gaseous nitrogen (GN_2) supply and a vacuum system that generates a vacuum of 1x10E-3 Torr.

3.2.2.4 Water Services - The SSF Services model will provide a water servicer capable of providing a minimum total water flow of 400 lbs/hr (200 lbs/hr to SSFF CFS avionics and 100 lbs/hr to each FEP.) The water servicer will provide water temperature of 24.5°C to SSFF CFS avionics and to each FEP. The water servicer will be capable of receiving water temperatures of 52.0 °C and 58.0°C from the FEPs and 47.0 °C from the SSFF CFS avionics while maintaining the 24.5 °C outlet water temperature.

3.2.3 SSFF Core Facility Services Model

The SSFF Core Facility Services model will perform the following functions: command and data management, subsystem control, power distribution, power conditioning, signal conditioning, gas distribution, and thermal control. These functions are described in the following paragraphs.

3.2.3.1 Command and Data Management - The SSFF CFS model will acquire telemetry data from the subsystems within the SSFF CFS model and from the FEPs. Selected parameters will be processed and displayed on the console in real-time during the simulated sample processing runs. All telemetry data will be transferred to the GSS model. The SSFF CFS model will provide a user interface for initiating commands from the keyboard, and it will accept commands initiated from the GSS model.

3.2.3.2 Subsystem Control - The SSFF CFS model will provide subsystem control for the power distribution, power conditioning, gas distribution and thermal control functions. The SSFF CFS will also provide control of the FEP model furnace heating system (FHS). The control of the gas distribution and the FEP model FHS will be driven by timelines and will be sample dependent.

3.2.3.3 Power Distribution - The SSFF CF model will provide a power distribution function as required for the SSFF CFS model functions and for FEP model FHS. The SSFF CFS model will also provide sensors required to status the core power distribution function.

3.2.3.4 Power Conditioning - The SSFF CFS model will provide a power conditioning function which is configurable to control a CGF and/or a PMZF. This function will provide 30 individually controllable power modules for each FEP. Each power module will be capable of delivering 16.7 Amps at 12.0 volts. The SSFF CFS model will also provide sensors required to status the power conditioning function.

3.2.3.5 Signal Conditioning - The SSFF CFS model will provide signal conditioning for sensors located in the SSFF CFS model. It will also provide sensors required to status the signal conditioning function.

3.2.3.6 Gas Distribution - The SSFF CFS model will provide a 3000 psi argon supply. An interface to the SSF Services model GN_2 supply and vacuum vent system will also be provided. Gas lines, valves and regulators will be supplied as required to control the argon and GN_2 supplies and the vacuum venting. The SSFF CFS model will provide the sensors required to status the gas distribution function.

3.2.3.7 Thermal Control - The SSFF CFS model will provide an interface to the SSF Services model water servicer. The CFS model will also provide all water lines, valves, regulators and filters required to control the water flow. Sensors required to status the thermal control function will also be provided.

3.2.4 SSFF Furnace Experiment Package Model

The SSFF Furnace Experiment Package model will perform the following functions related to the SSFF FEP: remote sensor acquisition, furnace heating system functions, thermal and gas interfaces and characteristics.

3.2.4.1 Remote Sensor Acquisition - The SSFF FEP model will provide a remote sensing device which performs signal conditioning for the FEP sensors and acquires the sensor data. This device will digitize the sensor data and transfer it to the SSFF CFS model upon request.

3.2.4.2 Furnace Heating System Functions - The SSFF FEP model will provide a variable load model (0 to 20.0 Amps) with 5 ohms being the minimum load available. A temperature model that is dependent upon the input control voltage and current, a variable rate control, transfer ratio, and thermocouple selection (K or S type) will also be provided. The SSFF FEP will provide the sensors necessary to status the FHS functions.

3.2.4.3 Thermal and Gas Interface and Characteristics - The SSFF FEP model will provide an experiment interface to the SSFF CFS thermal control function and gas distribution function. The thermal interface and characteristics model will be capable of heating the water in the core avionics water line up to 47.0°C. It will be capable of heating the water in the FEP water lines to 58.0°C. The gas interface and characteristics model will provide, for each FEP, an Experiment Apparatus Container (EAC) capable of containing from 0.1 psi to 14.7 psi of argon or GN_2.

3.3 DESIGN DESCRIPTION

The SSFF development model functions described in section 3.2 are implemented by five (5) subsystems. Each of these subsystems perform functions in some or all of the three functional categories: SSF Services, SSFF CFS, and SSFF FEP. The design of the subsystems are described in sections 3.3.1 through 3.3.5. Appendix B contains a cross-reference between the development model functions defined in section 3.2 of this document and the design defined in this section.

3.3.1 Data Management Subsystem

The Data Management Subsystem (DMS) is comprised of the GSS, SSFF CFS, and SSFF FEP computer systems and peripherals. The SSFF CFS computer models the Core Control Unit (CCU). The SSFF FEP computers model the Furnace Control Units (FCU's). The DMS is designed to support the command and data management functions and the subsystem control functions of the SSFF development model. Figure 3.3.1-1 depicts the overall design of the DMS. Paragraphs 3.3.1.1 through 3.3.1.5 describe the design of the DMS.

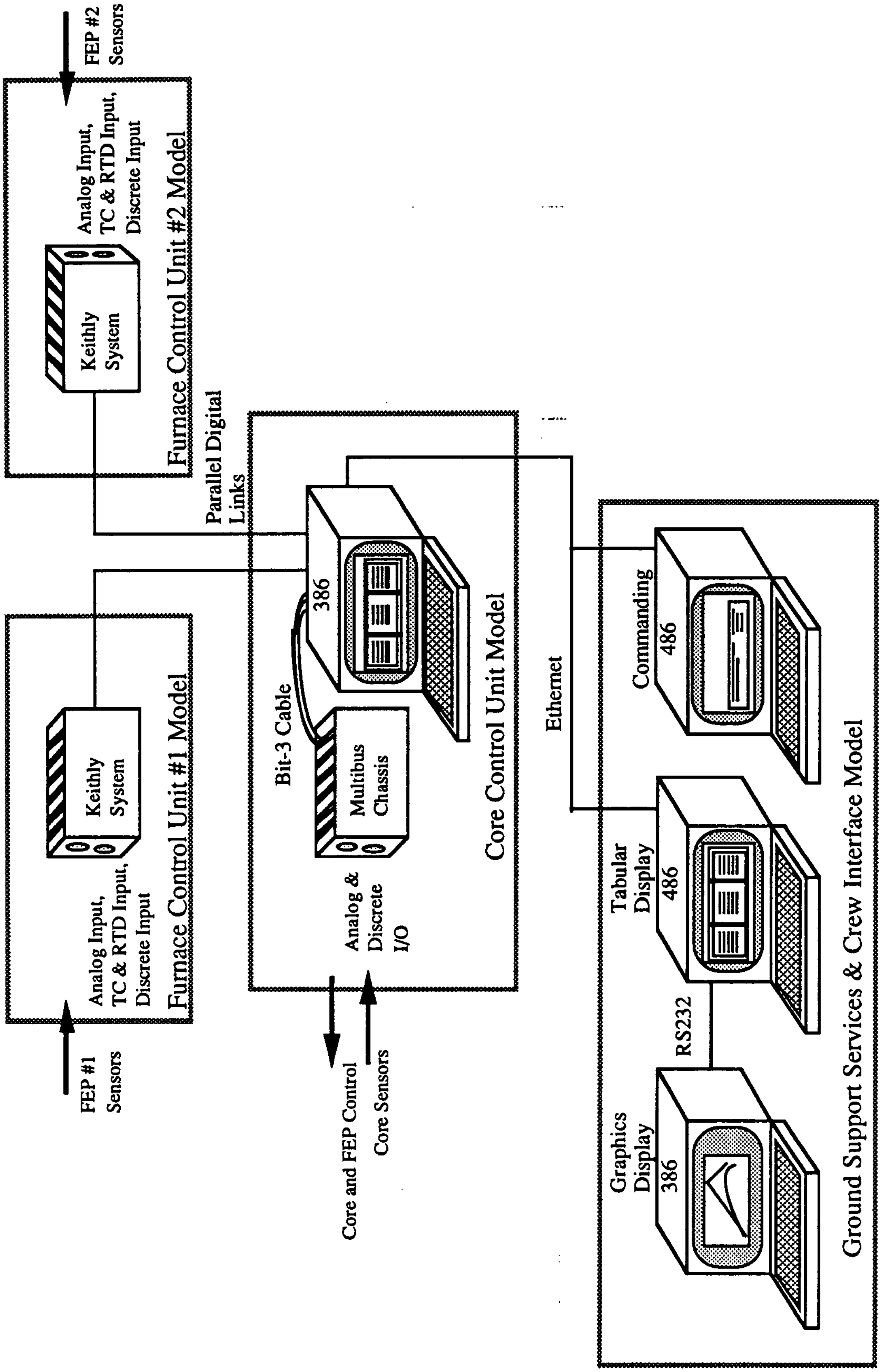

FIGURE 3.3.1-1 DATA MANAGEMENT SUBSYSTEM OVERALL DESIGN

3.3.1.1 DMS Interfaces - The GSS Services computers communicate with the CCU model via the SSF Data Management System communications link. The link is modeled using ethernet, a serial digital communications link similar to the candidate communications links that will be used on the SSF. The CCU model communicates with each FEP computer via a digital parallel link.

3.3.1.2 GSS Computer Model - This system is comprised of three computers: two 486 personal computers (PC) and a 386 PC. The 486 PC's consists of a 14" console, keyboard, computer chassis with a 80486 microprocessor, an ethernet communications card, 16 megabytes of Random Access Memory (RAM), 330 megabytes of fixed disk storage, and two RS232 ports. The 386 PC consists of a 12" console, keyboard, computer chassis with a 80386 microprocessor, 16 megabytes of RAM, 330 megabytes of fixed disk storage, and two RS232 ports.

The software that executes on the GSS computer model consists of the DOS operating system and the Core Facility Support Software (CSS). The CSS is a modified version of the CGF Ground Support Equipment software. It models both the GSS and SSFF CFS command and display functions as well as the GSS database maintenance functions. Figure 3.3.1.2-1 depicts the high level design of the CSS software. For further information on the CSS, refer to SSFF memorandum, SSFF-91-0039, dated August 30, 1991.

3.3.1.3 SSFF CFS Core Control Unit Model - The CCU hardware consists of a computer chassis with an 80836 microprocessor, an ethernet communications card, 8 megabytes of RAM, 330 megabytes of fixed disk storage, two RS232 ports, a BIT-3 PC to Multibus interface, and a Multibus chassis with 144 TTL level discrete input/output ports, 30 0-10 Vdc analog input ports, and 64 0-10 Vdc analog output ports.

The Core Data Acquisition and Control Software (COREDACS) executes on the CCU. The COREDACS consists of the VRTX-386 operating system, application independent software (AIS) libraries, and application dependent software (ADS). The AIS consists of a group of input/output routines used to interface with the development model hardware. The ADS is based on the CGF Control and Data Acquisition System ADS. Figure 3.3.1.3-1 depicts the high level design of the COREDACS. Figure 3.3.1.3-2 depicts the operational states of the COREDACS. Further definition of the COREDACS will be documented in an SSFF memorandum.

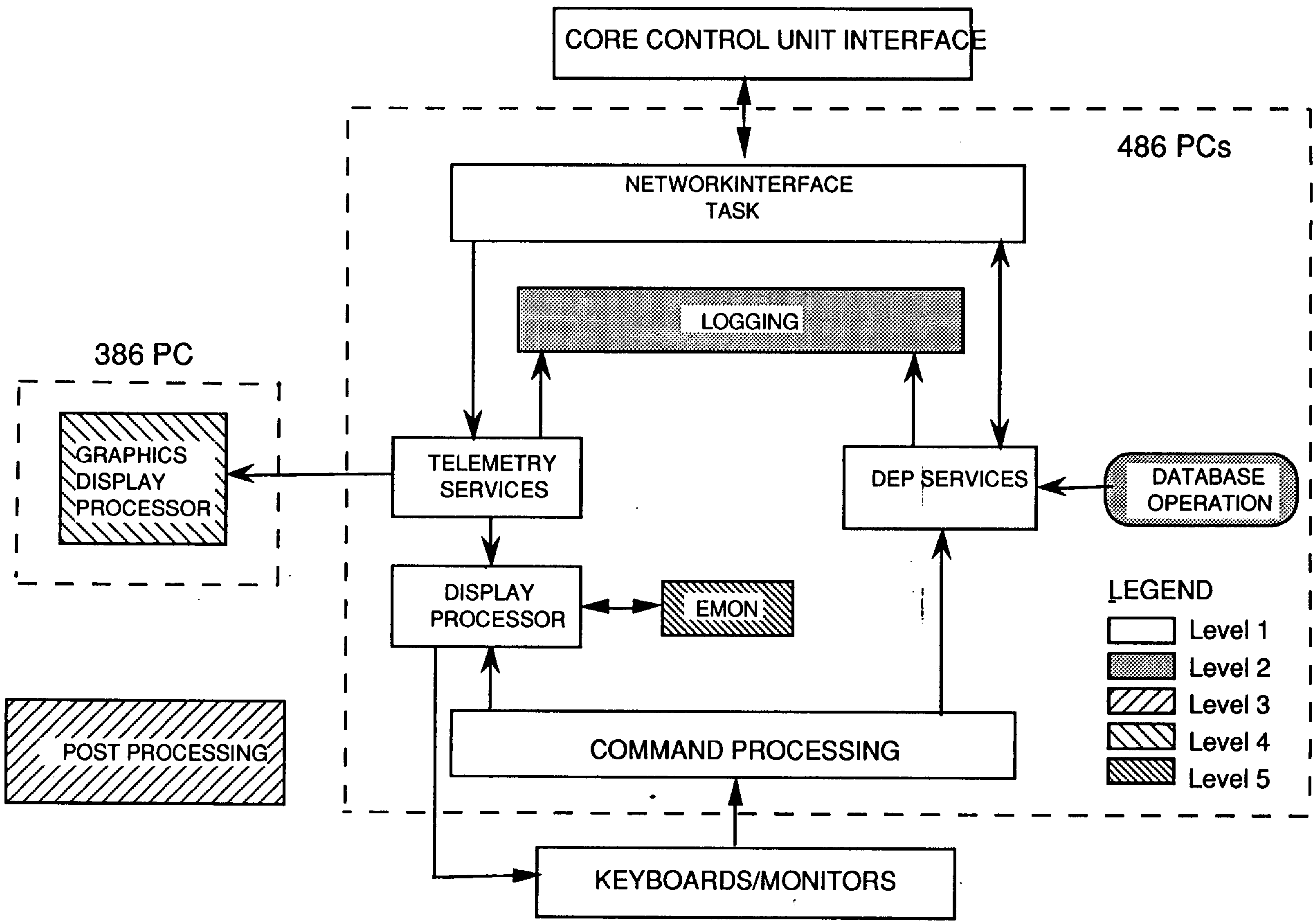

FIGURE 3.3.1.2-1 COMMAND AND CONTROL SUPPORT SOFTW ARE

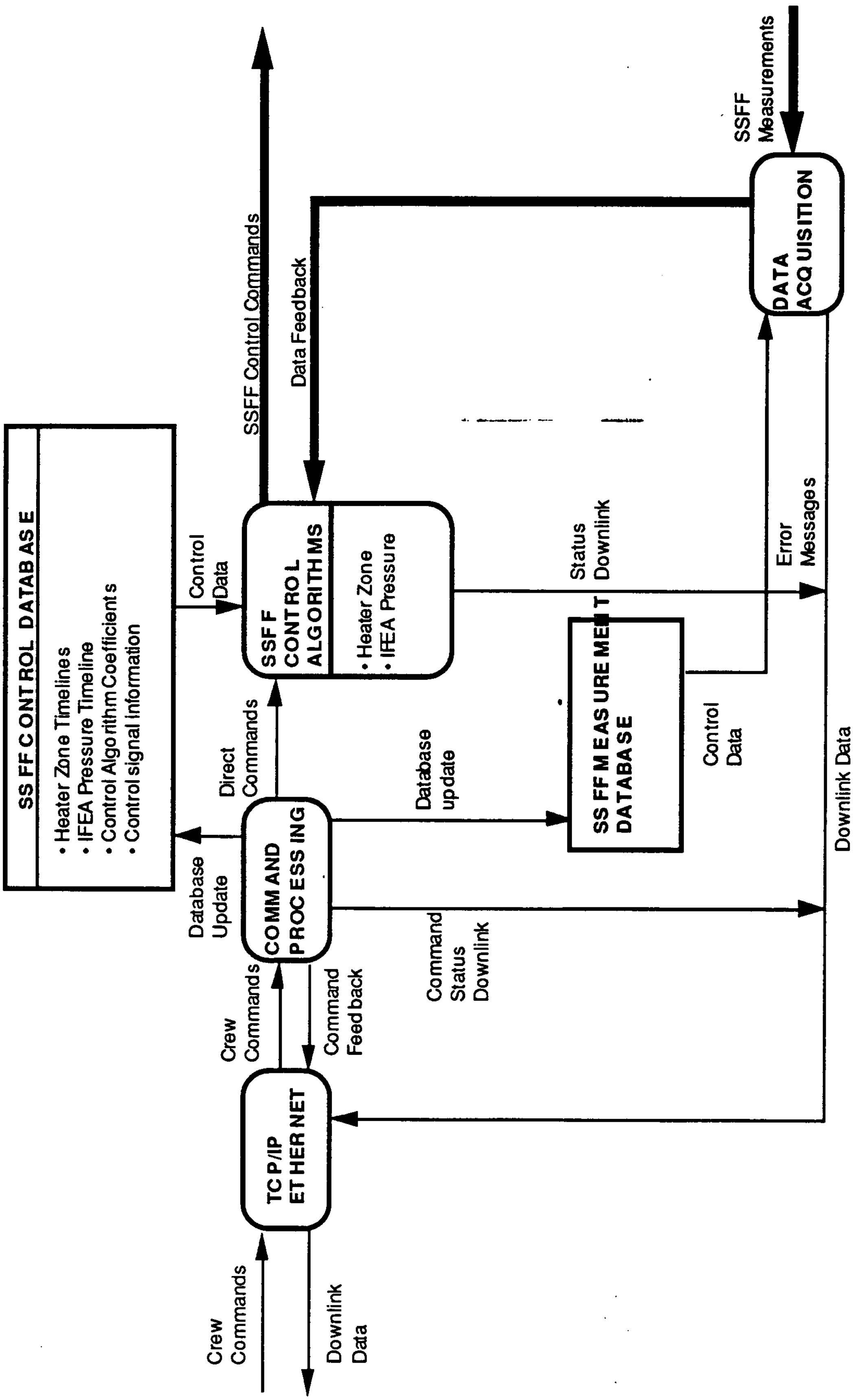

FIGURE 3.3.1.3-1 CORE DATA ACQUISITION AND CONTROL SOFTWARE

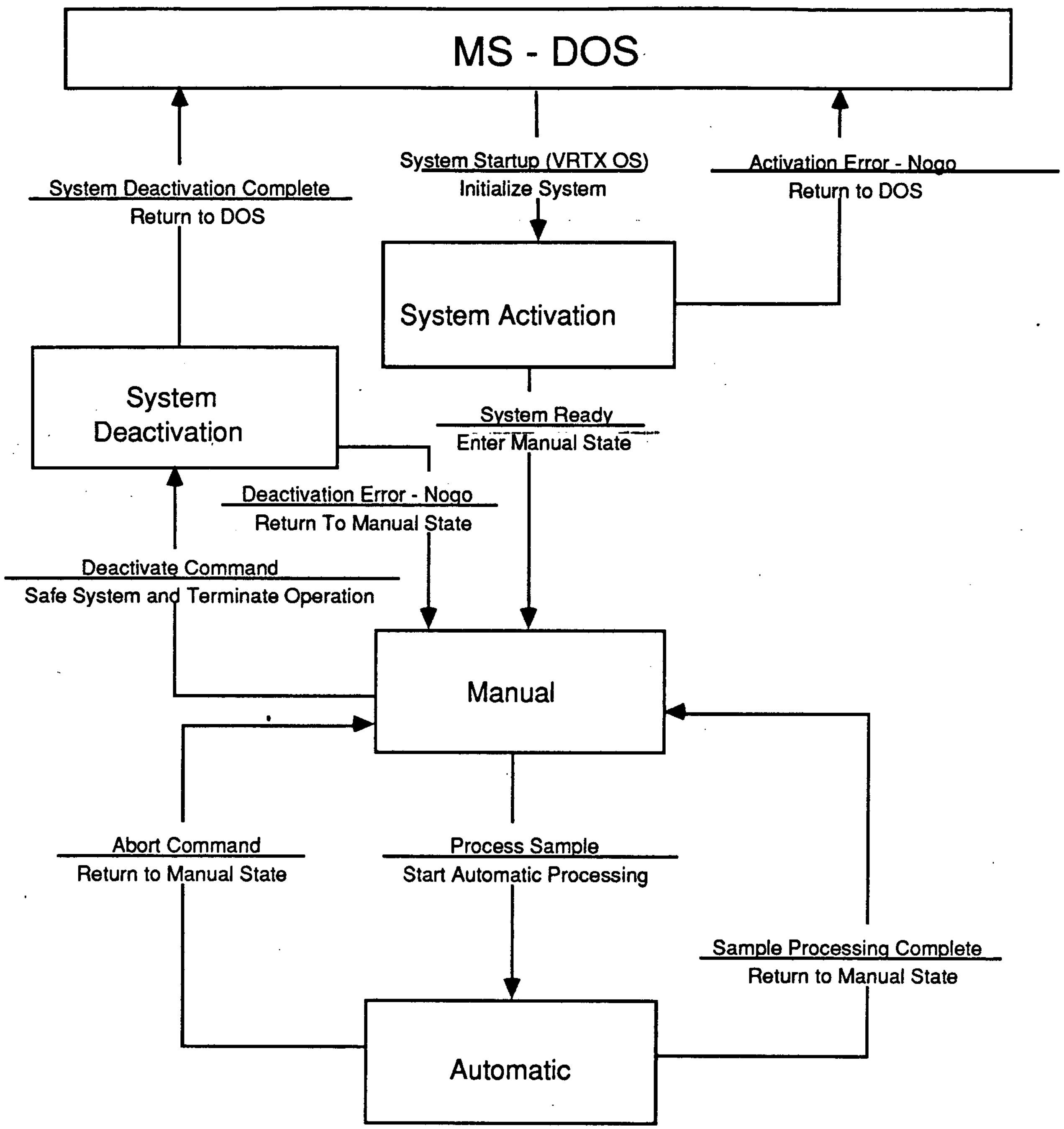

FIGURE 3.3.1.3-2 COREDACS OPERATIONAL STATES

3.3.1.4 SSFF FEP Furnace Control Unit Model - The data acquisition functions of the FEP computer are being modeled by the FCU. The furnace control functions of the FEP computer are modeled by the CCU. The FCU hardware consists of a computer chassis, six (6) Keithly boards: a serial interface board, an analog input board (16 0-10 Vdc channels), an isolated analog input board (8 0-10 Vdc isolated channels), a signal conditioning board (14 isolated millivolt input channels and 2 Bridge input channels), and RTD interface board (8 channels) and an RTD expander board (8 channels). The software is integral to the system and is provided with the system by the manufacturer. Figure 3.3.1.4-1 depicts the configuration of the FCU.

3.3.1.5 SSFF FEP Heater Load and Temperature Model - Although the heater load and temperature model is not a computer-based system, it is integral to the SSFF CFS subsystem control function, thus it is being discussed with the DMS design.

The heater load model provides a load that is variable via a front panel dial. This load inputs a control voltage from the power modules and outputs a voltage and current to the temperature model. The temperature model converts the voltage and current, via a transfer ratio and a variable (by potentiometer) rate control, to a voltage that is divided by an S thermocouple constant or a K thermocouple constant (jumper selectable). This value is used to produce two identical millivolt outputs which represent the thermocouple readings. The heater load model also provides a temperature indicator which represents a reference junction temperature. The reset function sets the simulated thermocouple outputs to zero. Figure 3.3.1.5-1 depicts the design of the heater load and temperature model.

3.3.2 Power Conditioning and Distribution Subsystem

The Power Conditioning and Distribution Subsystem (PCDS) is comprised the power of the SSF Services power model, the SSFF CFS Core Power Distributor (CPD) and the SSFF CFS Core Power Conditioner (CPC). Figure 3.3.2-1 depicts the overall design of the PCDS for the development model.

3.3.2.1 SSF Services Power Model - The SSF Services power model consists of two 120 Vdc power supplies, one 3000 watt supply and one 1000 watt supply. The SSF Services power model also provides two 110 Vac power lines for the CCU computer chassis and monitor, the GSS model computers, and to the solenoid valves. Although the SSF does not provide 110 Vac,

KEITHLEY SYSTEM

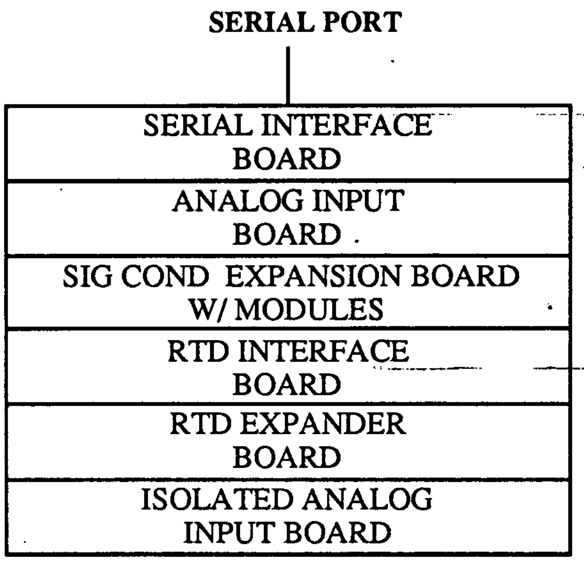

FIGURE 3.3.1.4-1 FURNACE CONTROL UNIT MODEL

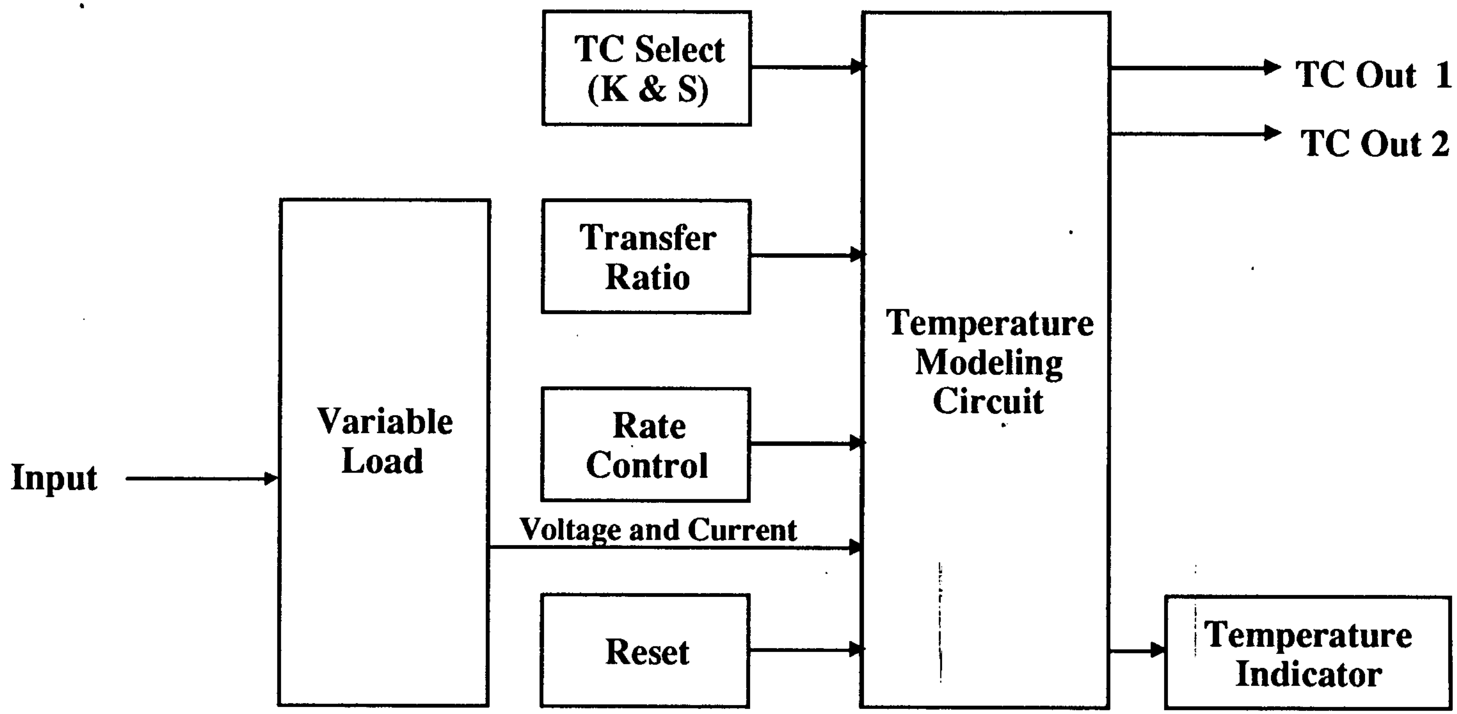

FIGURE 3.3.1.5-1 HEATER LOAD AND TEMPERATURE MODEL

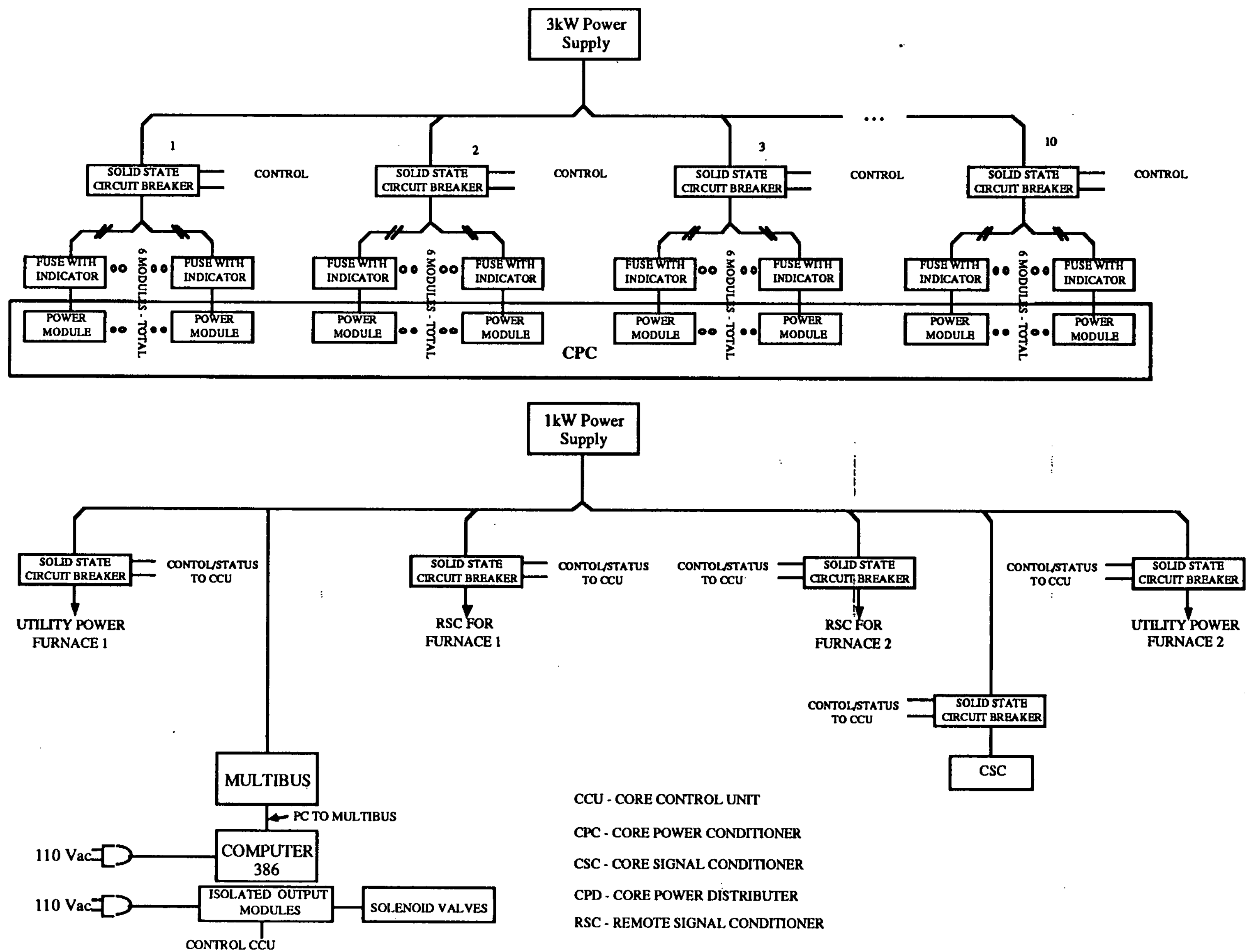

FIGURE 3.3.2-1 POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM

this power is used by the model where convenient because of the lower cost associated with purchasing solenoid valves and computers which operate on ac power while still maintaining functional equivalency.

3.3.2.2 SSFF CFS Core Power Distributor Model - The power distribution function is implemented by the SSFF CFS CPD. In the SSFF CFS CPD model, the 3000 watt power supply is used to power the sixty (60) power modules used for the furnace heating system control. A fuse (approximately 3 amps) with an indicator is located in-line with each power module. A 20 amp solid state circuit breaker is located in-line every 6 power modules. The control for each of the solid state circuit breakers are interfaced to the CCU.

The 1000 watt power supply is used to provide power to the CCU multibus chassis, power to the signal conditioners, FEP model utility power, and power for each FEP model FCU. A remote power controller (20 amp) is located in-line with each of the FEP model utility powers and FCUs. The control and status for each of the remote power controllers are interfaced to the CCU.

3.3.2.3 SSFF CFS Core Power Conditioner Model - The power conditioning function is implemented by the SSFF CFS CPC. The CPC is comprised of sixty (60) Vicor power modules, thirty (30) for each furnace. Each power module outputs 0-12 Vdc, 200 watts maximum. Figure 3.3.2.3-1 depicts the Vicor power module selected for the CPC. In order to meet the requirement to support a CGF like furnace and a PMZF like furnace, the power modules are "stacked" as required by the cabling between the CF model and the FEP model. For example, when controlling a CGF like furnace, five (5) modules are "stacked" to power the hot main heater (900 w) and two are "stacked" to power the hot guard heater (250 w), and so forth, for all seven of the CGF heaters. For the PMZF like furnace, one module could be used to power each of the heaters (200 w each). Figure 3.3.2.3-2 depicts this "stacking" scheme.

3.3.3 SSFF CFS Signal Conditioning Subsystem

The SSFF CFS signal conditioning subsystem consists of the Core Monitor and Control - Signal Conditioner (CMC-SC). The CMC-SC provides 16 signal conditioning input channels for the CFS model sensors such as the main bus voltage and current, the pressure transducers, temperature sensors, and flow meters located in the core rack.

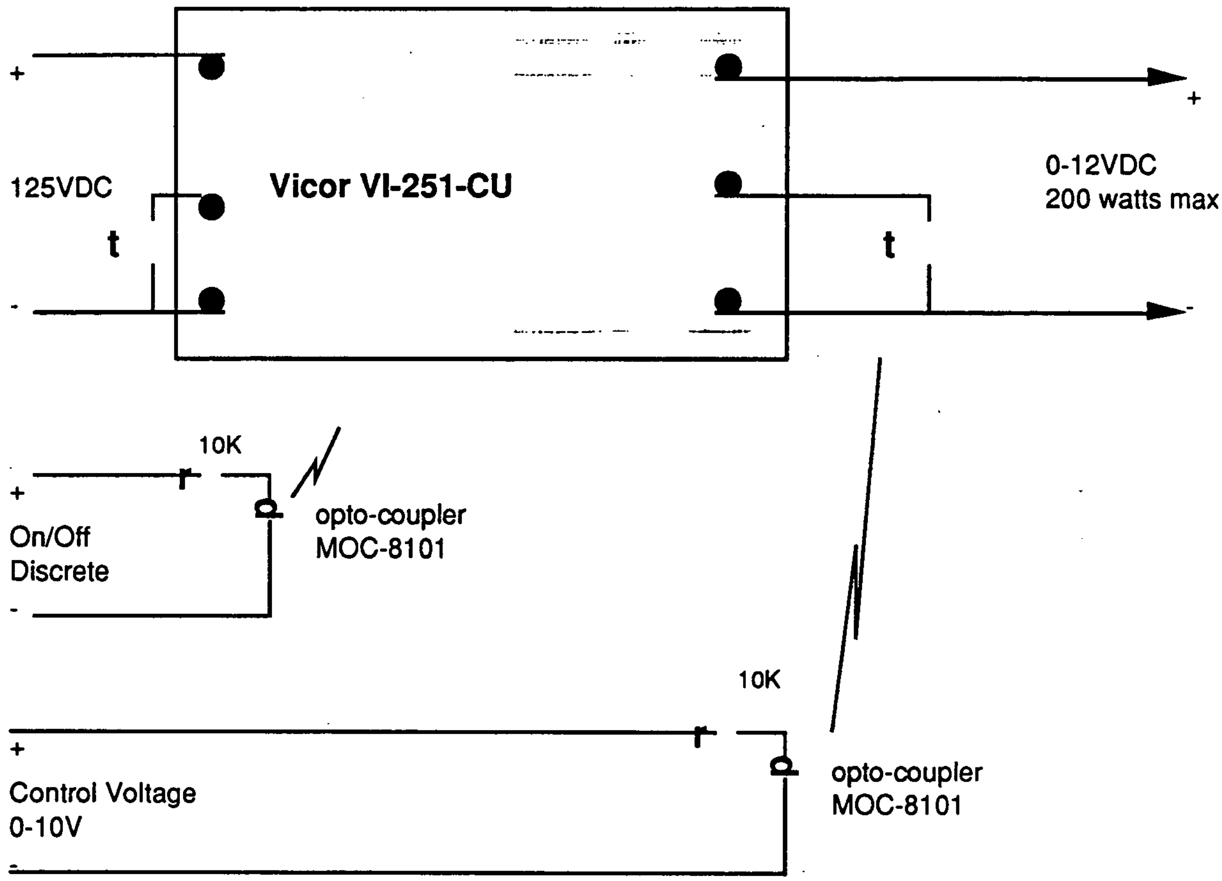

FIGURE 3.3.2.3-1 VICOR POWER MODULE

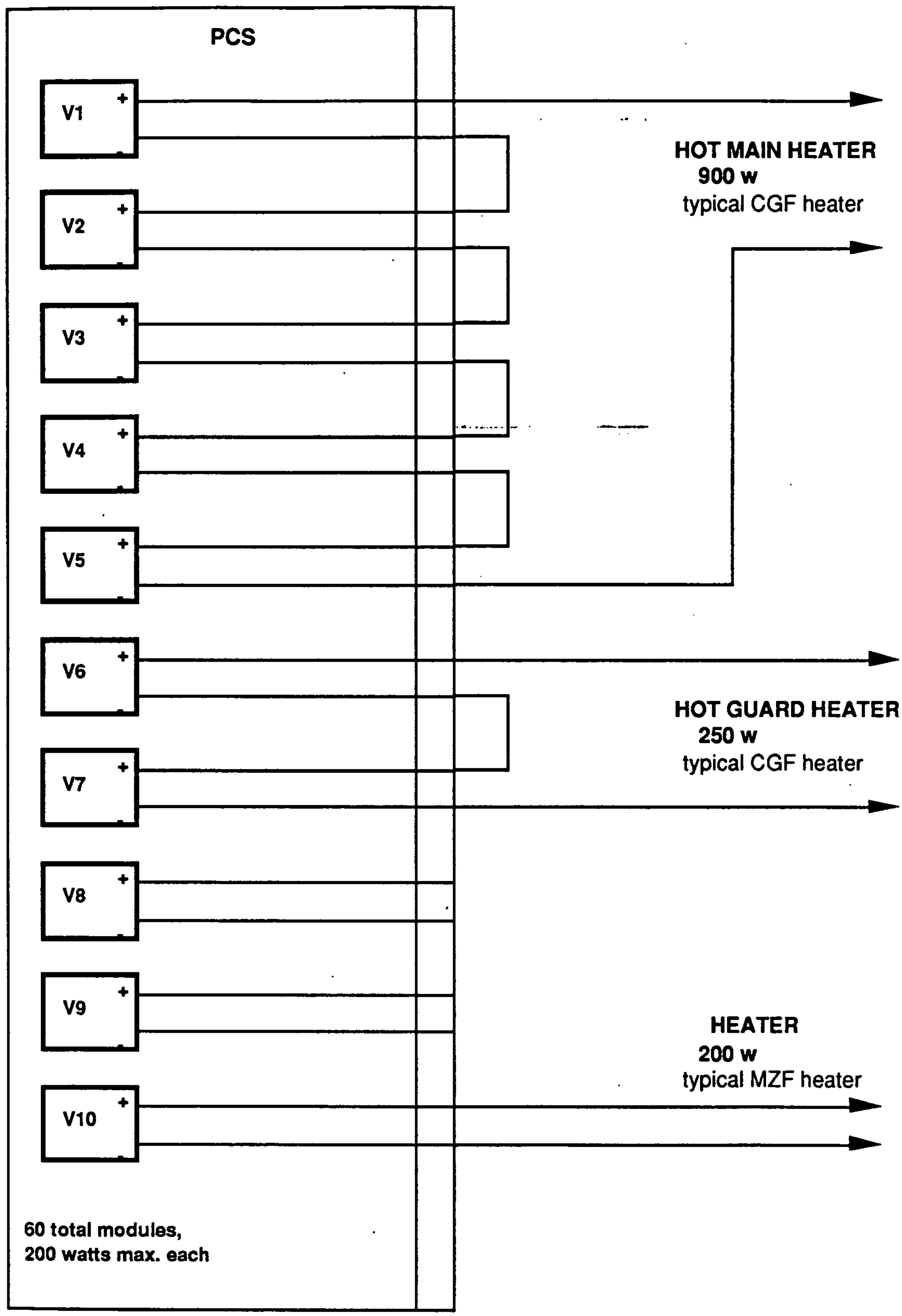

FIGURE 3.3.2.3-2 POWER MODULE STACKING SCHEME

3.3.4 Gas Distribution Subsystem

The gas distribution subsystem (GDS) is comprised of the SSF Services GN_2 supply and vacuum vent system model, the SSFF CFS GDS model, and the SSFF FEP EAC model. Figure 3.3.4-1 depicts the overall design of the GDS.

3.3.4.1 SSF Services GN_2 and Vacuum Vent Model - The SSF services for the GDS are modeled using a TBD psi bottle of GN_2 and a vacuum pump. The GN_2 bottle has a built-in regulator which regulates the gas to a constant pressure of approximately 90 psi. The vacuum pump provides a vacuum of 1x10E-3 Torr.

3.3.4.2 SSFF CFS Gas Distribution Subsystem Model - The CFS GDS model provides a 3000 psi bottle of argon and an interface to the SSF Services model GN_2 supply. The argon supply is used to pressurize the furnace EAC during simulated sample processing. The GN_2 supply is used to purge the atmosphere in the EAC between sample processing as required. The gas lines for the GN_2 and argon are connected to each other prior to the regulators via a bypass line. The solenoid valve in the bypass line is normally closed, however, in the event of a regulator failure, the valve may be opened to allow argon to be regulated by the GN_2 regulator or visa versa. The other solenoid valves in the core rack are used to control whether argon, GN_2 or no gas is flowing to the furnace racks. The regulators in each line are set to regulate the gas to the FEPs to approximately 20 psi. Pressure relief valves (PRVs) in the core rack are set to approximately 100 psi, and the PRVs in each furnace rack are set to approximately 25 psi.

3.3.4.3 SSFF FEP Experiment Apparatus Container Model - Each SSFF FEP GDS model is an empty EAC that is capable of being pressurized and evacuated.

3.3.5 Thermal Control Subsystem

The thermal control subsystem (TCS) is comprised of the SSF Services water services model, the SSFF CFS TCS model and the SSFF FEP heater model. Figure 3.3.5-1 depicts the overall design of the TCS.

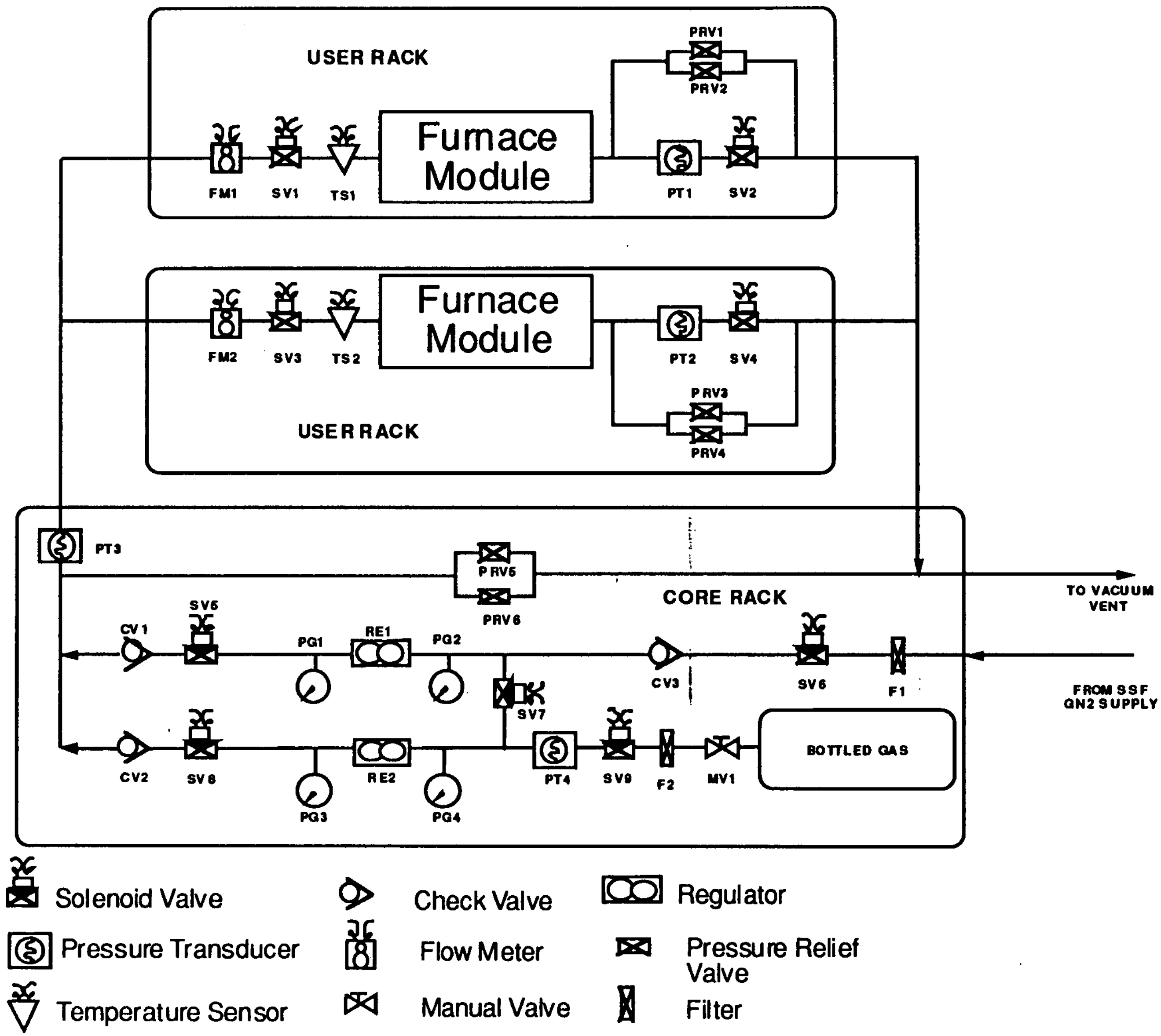

FIGURE 3.3.4-1 GAS DISTRIBUTION SUBSYSTEM

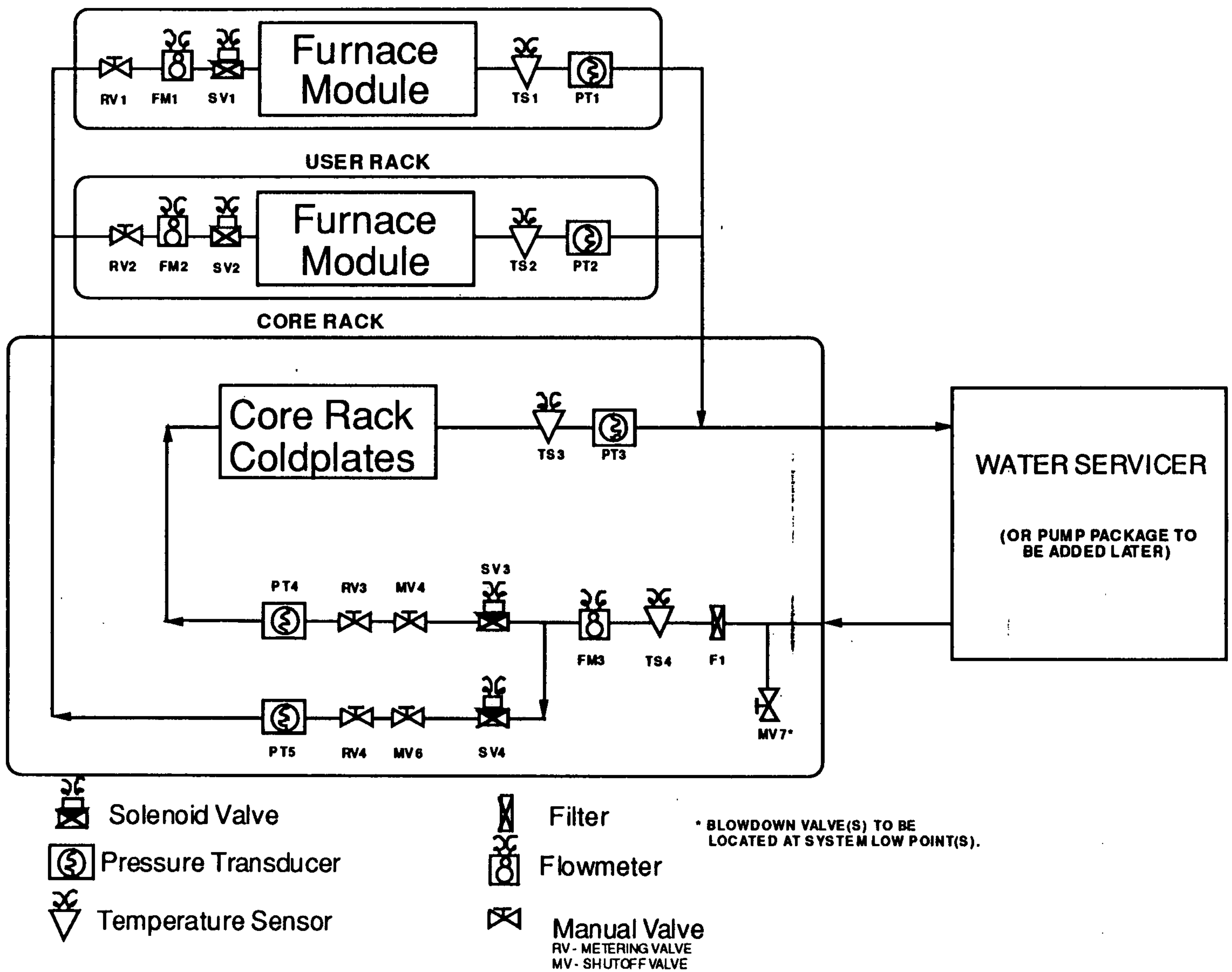

FIGURE 3.3.5-1 THERMAL CONTROL SUBSYSTEM

3.3.5.1 SSF Water Services Model - The SSF water services model consists of water servicer that recirculates water and is capable of removing 6200 watts at 20 °C. The maximum flow rate provided by the water servicer is 2000 lbs/hour at 15 psi and 1500 lbs/hour at 60 psi.

3.3.5.2 SSFF CFS Thermal Control Subsystem Model - The SSFF CFS TCS model provides an three cooling loops, one for the core rack and one for each FEP. The manual regulator valves are set to 200 lbs/hour to the FEP and to 100 lbs/hour to the core rack coldplate model. Solenoid valves are provided to allow software to start and stop flow to the core rack and/or to the FEPs. A manual blowdown valve is provided for use during servicing. The core rack coldplate model is a manually controlled heater that is capable of dissipating TBD watts.

3.3.5.3 SSFF FEP Heater Model - Each SSFF FEP heater model is a manually controlled heater capable of dissipating TBD watts. These heaters are identical to the heater used to model the core rack coldplates.

4.0 WORK DESCRIPTION

This section details the description of the efforts required to implement the development model. It includes the work tasks and their relationships to each other in terms of sequence and time phasing.

4.1 DEVELOPMENT APPROACH

An overall view of the development approach for the SSFF development model is shown graphically in Figure 4.1-1. The work tasks performed are shown as a process that flows from left to right and indicates the sequence and relationships of tasks to implement the development model. The lines with arrows between the tasks indicate that ~~a task must be~~ completed before the next task can begin.

First, the development model functional and performance requirements are defined. These requirements are defined in sufficient detail so that the hardware and software requirements may be allocated and defined. After this activity is performed, the hardware and software development phases begin.

The hardware and software development activities are shown overlapping the integration activities because of the interrelationship between the activities. Some of the integration effort will be performed during the hardware and software implementation and testing phases because of the need to exercise some hardware components with software, and the need to verify software interfaces with hardware.

After integration testing is complete, the demonstration tests are performed.

The development approach is the same for reconfiguration of the development model, for substitution of a different furnace, or the addition of a furnace for operation of multiple furnaces. In this case, the development model has been previously configured, so the effort consists of adapting the existing components will to operate with the new furnace requirements and implementing new hardware, software, and/or operational functions.

The approach to add a prototype flight component is also the same. In this case, the addition is handled as a reconfiguration of the existing equipment.

Each of the major parts of the development process is discussed in the following paragraphs.

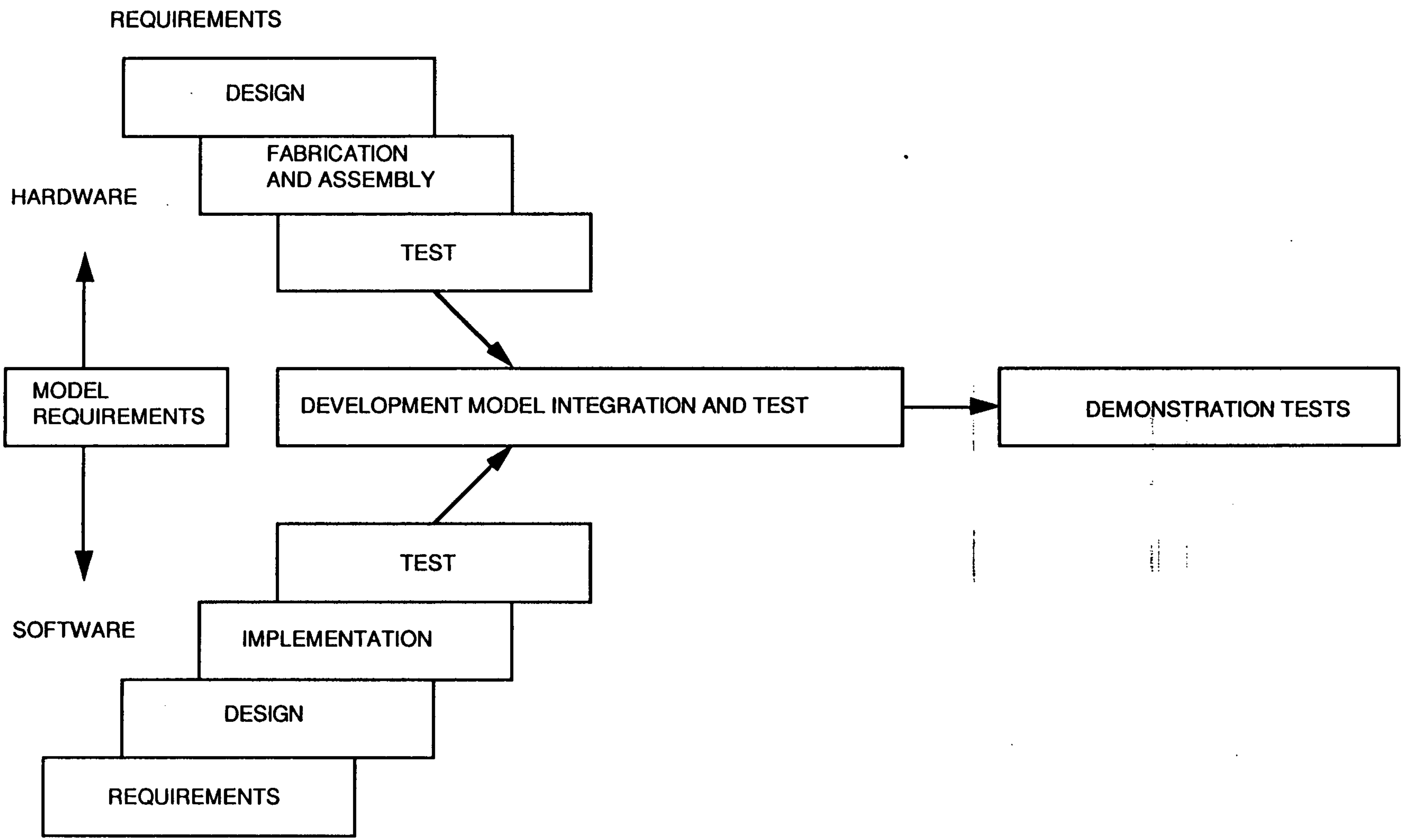

FIGURE 4.1-1. DEVELOPMENT MODEL IMPLEMENTATION APPROACH

4.2 SYSTEM DESIGN AND DEVELOPMENT

System design and development includes all of those activities at the system level that are required to implement the system as a whole. These are the formulation of the functional and performance requirements, documentation of the system, plans for integrating the system, test and verification plans and procedures, plans for the integration of the furnace with the development model, and plans for the operational demonstration.

Specifically, the system design and development function includes the following tasks:

1. Prepare and maintain the Development Plan for the development model.
2. Provide integration co-ordination among the various components and disciplines, including engineering, software and test.
3. Provide interface definition and control for the development model.
4. Allocate system requirements to hardware and software.
5. Define database requirements, display requirements, and telemetry stream formats for each configuration of the development model.
6. Review hardware and software designs to ensure that system objectives are being met.
7. Co-ordinate the final system demonstration.

4.3 HARDWARE DEVELOPMENT

The hardware development process can be divided up into the requirements definition phase, the design phase, the fabrication phase, and the test and checkout phase. The system will be developed so that it can be upgraded in order to follow along with changes in the flight design.

c3.4.3.1 Requirements Definition

The main goal of the development model is to prove that SSFF system is a feasible concept. Because of this the development model requirements are functional in nature instead of imposing system accuracy requirements.

The requirements for the hardware design are derived from the flight concept at the Conceptual Design Review (CoDR). This is done so that the development model can be baselined. Once the development model is operational the flight concept will be re-evaluated and changes that are made will be incorporated into the system as necessary to prove the feasibility of the SSFF concept.

4.3.2 Design

Instead of modeling the physical size of the SSFF system the design will be done to model functionality. Although some custom designed hardware will be required to complete the system, the design will be done using commercial available hardware (i.e. where computers are needed, PC's will be used instead of an imbedded processor). The design will also be done in such a manner that upgrades can be made to follow along with the flight system concept. While the design progresses, parts selection and procurement will proceed in parallel in order to maintain schedule.

Sketches will be used in order to communicate the design. This documentation is only to be to the level ~~necessary to complete~~ the development model. The channel assignments will be documented in order to provide this information to the software personnel.

4.3.3 Fabrication

The fabrication of the system will be performed to good commercial practices. Most machined or sheet metal parts will be manufactured in the shop and assembly of the system will be done by technicians in an informal lab environment.

4.3.4 Test and Checkout

Hardware test and checkout will be done at the component or assembly level. System checkout will be done prior to turning the system over for software integration and demonstration testing. The checkout is to be done using a minimal amount of software and breakout boxes. This checkout will be done primarily to verify the hardware configuration, functionality, and channel assignments prior to system checkout with the functional software.

4.4 SOFTWARE DEVELOPMENT

The overall software development effort is divided into logical phases : requirements analysis and interface definition, design, code and unit test, and integrated test. Because the system is a development model, the software development phases closely resemble the phases used in rapid prototyping. The primary difference between a standard software development cycle and the SSFF software development cycle is that coding of development model software will begin during the requirements analysis phase. This approach

will provide the flexibility necessary for a development model in which the detailed functional requirements are rather volatile.

A discussion on each phase in the life cycle is given in the following paragraphs.

4.4.1 Requirements Analysis and Interface Definition

The requirements analysis and interface definition phase consists of collecting, analyzing, integrating, and defining in algorithmic terms, the functional requirements of the system specification. These functional requirements will be combined with interface and performance requirements to provide the basis for the software design, implementation, and testing activities covered herein.

The software requirements for the SSFF development model will be defined and maintained via SSFF memorandums. These memorandums will specify various configuration levels in order to provide priority for implementation. Because the CGF software requirements will form the basis of the SSFF development model software requirements, the requirements will be described in terms of the differences between CGF and SSFF.

Informal requirements reviews will be held as required by SSFF Development Model Systems Engineering.

4.4.2 Software Design

The software design phase will establish the structural and dynamic aspects of the software design, including the individual computer software component (CSC) functional and performance specifications, the data base design, definition of inter-CSC interfaces, and definition of the hardware/software interfaces. The CSCs of each Computer Software Configuration Item (CSCI) are identified and documented via memorandum during this phase.

The structural design of the CGF software will be used as a basis for the SSFF Development Model software. Modifications to the CGF structural design will be documented in SSFF memorandums.

Informal presentations of the software design will be conducted by the software development personnel as requested by the development model project manager.

4.4.3 Code and Unit Test

As previously mentioned, coding will begin during the requirements analysis phase. This coding will primarily consist of modifying CGF software

to the extent required to perform a minimum set of functions required by the SSFF development model (i.e. configuration level 1). These functions include the simultaneous operation of two CGF-like furnaces, with the exclusion of exception monitoring, the furnace translation system, sample exchange mechanism, and sample interface demarcation system.

As each module is completed, it will be integrated and informally unit tested to the extent possible on the development system. Programmers will design their own unit tests and inspect the results to ensure that the module is performing the logic specified in the design documentation.

Once all modules required for the minimum set of functions have been integrated into the software system, additional modules will be coded and/or existing modules will be modified to support the next level of requirements. Each integrated version of the software will be preserved so that it may be used while the next version is being developed. This process will continue, as time and budget allows, until all configuration levels have been achieved.

4.4.4 Integrated Software Test

The purpose of the integrated software tests will be to ensure that the nominal operation of software meets the functional requirements of the configuration level. These tests will be performed once all modules required for a particular configuration level have been unit tested and integrated into the software system. Although these tests are informal, they will be performed in accordance with predefined test outlines. Test logs will be maintained in order to provide traceability and as a means to record problems.

4.5 DEVELOPMENT MODEL INTEGRATION AND TEST

The development model hardware/software integration activities will be conducted in a "building block" manner. That is, the software will be integrated into the CCU initially, then hardware functions of the development model hardware will be added and incrementally tested until the entire SSFF development model has been integrated. As each hardware function is added, the respective software function(s) will be tested and modified, if required. When a hardware function is added, testing will be performed on previously integrated functions to some extent, although the focus of the testing will be on the newly integrated function.

After the entire SSFF development model hardware and software have been integrated and incrementally tested, tests which exercise the entire

system will be performed. Although these tests are informal, they will be performed in accordance with predefined test outlines. Test logs will be maintained in order to provide traceability and as a means to record problems. The integrated system tests will form the basis for determining when the system is ready for the demonstration tests.

The following list defines the plan for integration of software with the hardware.

1. Integrate the COREDACS into CCU
2. Integrate CPD, CSC, and CPC (Integrated CFS model)
3. Integrate one FCU
4. Integrate one Gas and Thermal Interface and Characteristics model
5. Integrate the second FCU
6. Integrate the second Gas and Thermal Interface and Characteristics model
7. Integrate one FHS Load and Temperature Model
8. Integrate the second FHS Load and Temperature Model (Integrated CFS and FEP models)
9. Integrate the GSS computers (Integrated SSFF development model)

4.6 DEMONSTRATION TEST

A separate demonstration test plan will be developed and maintained to define the demonstration test approach. This plan will be documented in an SSFF memorandum.

5.0 PROJECT MANAGEMENT

Project management provides the structure and activities for definition, direction and successful accomplishment of the SSFF development objectives listed in section 1.2. The structure and activities include the organization and responsibilities, schedule, and resources for performing the work, and are discussed in the following paragraphs.

5.1 ORGANIZATION AND RESPONSIBILITIES

The SSFF project is organized into areas that define the Work Breakdown Structure (WBS). Each is a functional ~~work~~ area ~~with~~ responsibilities for a part of the SSFF development. These areas are Project Management, Systems Engineering, Hardware Engineering, Software Engineering and Test. These functions are designed to work together to manage, specify, design, develop, manufacture, integrate and test the system.

5.1.1 Project Management

The work requirement is to perform management of the development model project. Specific tasks are listed below:

- Define project objectives.
- Co-ordinate all tasks.
- Provide work schedule with milestone.
- Provide project resources to accomplish tasks.
- Monitor all efforts to ensure compliance with contractual objectives, schedule and resource limits.

The Products of this effort are:

1) Working, proof-of-concept development model. This includes hardware and software.
2) Drawings, sketches and documentation as required to support the development effort.
3) Status reports. Briefings and reports to the customer at four month intervals.

5.1.2 System Engineering

The work requirement is to perform the system engineering effort for the development model. Specific tasks are listed below.

- Prepare and maintain the Development Plan for the development model.
- Provide integration co-ordination among the various components and disciplines. This includes engineering, software, and test.
- Provide interface definition and control for the development model.
- Co-ordinate the demonstration test.

The products of this effort are:

1) Development Plan.
2) System level Integration block diagram.
3) Demonstration Test Plan.

5.1.3 Hardware Engineering

The work requirement is to perform the hardware engineering effort for the development model. Specific tasks are listed below.

- Design, develop, and test the hardware for the Core facility and the SSF Services. Refer to the Development Plan for a definition of the components and their functional performance requirements.
- Identify the parts necessary for fabrication and support purchasing of the parts.
- Fabricate and assemble the electrical and mechanical hardware. This includes unpacking and ~~setup~~ of ~~purchased~~ materials, assembly of electrical and mechanical components, construction of electrical and electronic boards and assemblies, and fabrication of cable assemblies.
- Perform the integration and test of the components to provide a complete, functional system.

The products of this effort are:

1) Working hardware.
2) Sketches, drawings, parts list and other documentation necessary to support the design and fabrication of the development model. The documentation is informal and to best commercial practices.

5.1.4 Software Engineering

The work requirement is to perform the software engineering effort for the development model. Specific tasks are listed below.

- Design, develop, and test the software for the core facility and the SSF Services simulator. The concept, functional requirements and approach are described in the Development Plan.
- Identify software and software development tools required to support the development effort.
- Support purchasing of the software, software development tools and computer system.
- Support demonstration testing of the integrated system. This includes preparation of test timelines, providing testing support, and providing operator support during demonstration testing.
- Prepare informal documentation necessary to support the software development activity.

The products of this effort are:

1) Functional core Facility software program.
2) Functional SSF Services software program.
3) Documentation (best commercial practice) necessary to support the development effort.
4) Documentation, data bases, software, etc. to support the Demonstration Test.

5.1.5 System Testing

The work requirement is to perform the System Testing effort for the development model. Specific tasks are listed below.

- Plan and perform the system integration testing activities. These tests will be performed in co-ordination with hardware and software engineering.
- Co-ordinate and perform the Demonstration Test. This includes arranging and scheduling of necessary resources to support the test, co-ordination of these activities to perform the test, providing means to store and interpret test data, and informal documentation of test results.

The products of this effort are:

1) Test data.
2) Test report (informal).

5.2 SCHEDULE

The schedule for the Development Model is shown in figure 6.2-1. It shows a 14 month schedule for the design, development, fabrication and test of the system. The hardware and software development tasks will be performed in parallel to the maximum extent possible in order to meet this aggressive schedule.

Milestones are shown for critical events in the schedule. Some of the most critical events are for the purchase of parts and assemblies. With delivery lead times a potential problem, the parts and assemblies need to be identified and ordered as soon as possible in the schedule in order to meet the fabrication milestones.

The schedule also shows the Program review milestones. Quarterly reviews are scheduled along with a Requirements Definition Review in September of 1991. At this review the design of the hardware and software should be sufficiently detailed to indicate the feasibility of the SSFF concept, and to indicate the planned success of the Demonstration Test for the Development Model.

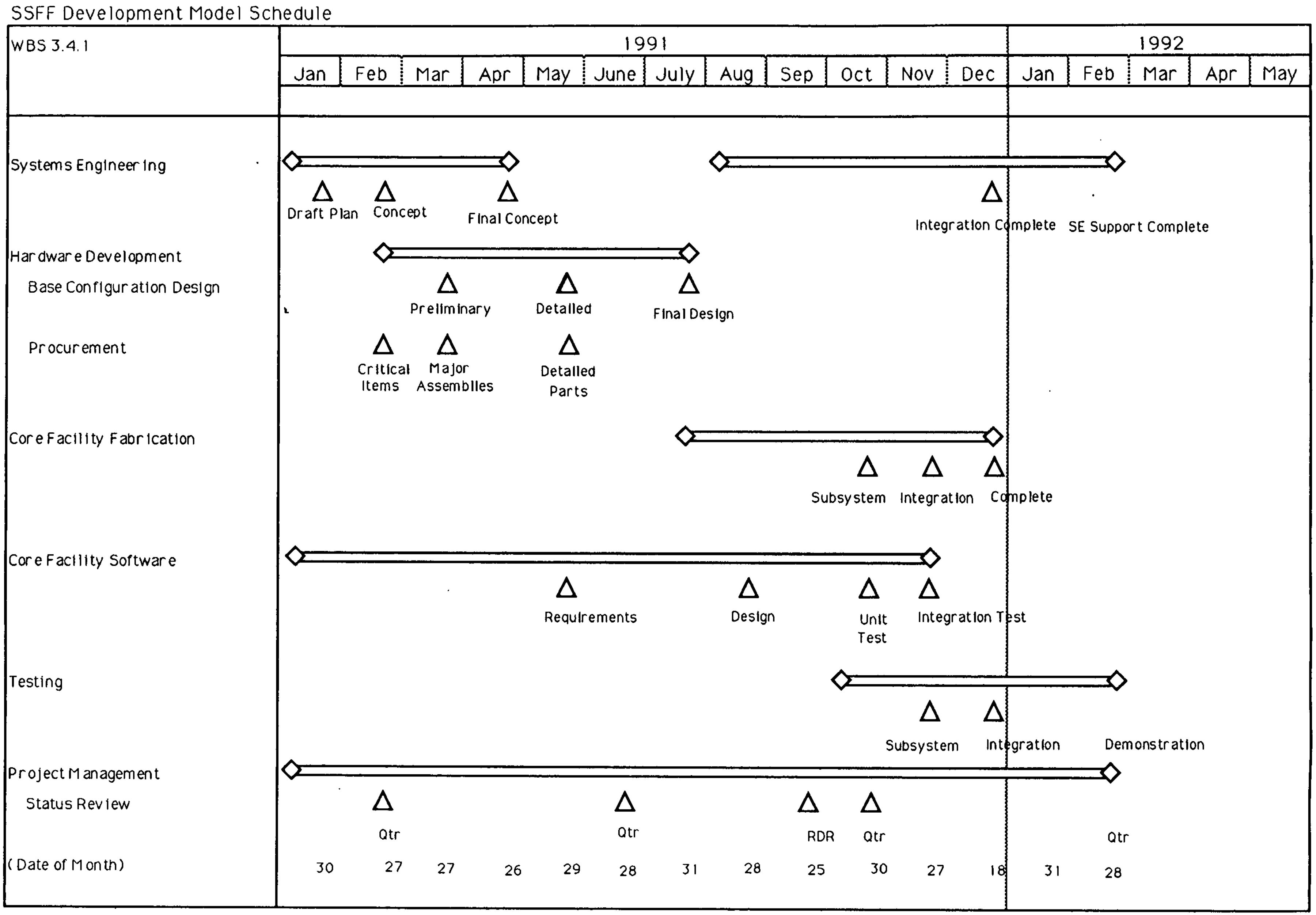

Figure 5.2-1 Development Model Schedule

5.3 DOCUMENTATION

Since this is a Development Model designed to show feasibility of the SSFF concept and the system is designed for a laboratory environment, formal documentation is not required. Documentation will be produced to meet the needs of the development effort and to communicate information needed for design, fabrication and test. The objective is to limit the cost of the documentation effort in order to devote the most time and resources to the engineering, test, and performance demonstration efforts.

System engineering documentation will include informal definitions of interfaces and performance objectives. This will include a system block diagram and hardware/software interface definitions for the design of the software. Documentation includes this Development Plan.

The hardware documentation will include sketches of cables assemblies, mechanical assemblies, interconnect drawings, and schematics. Computer Aided Design drawings may be produced where detail is required in order to fabricate parts.

Software documentation will be informal and produced only in order to communicate design and operational information.

Test documentation will include an informal Demonstration Test Plan and procedures. Test data will be produced in the form of graphical presentation of the test results.

6.0 FACILITIES AND TOOLS

This section describes the facilities and tools necessary to support the construction and operation of the development model. It includes the physical facilities and resources, and the engineering tools to support the development and operation of the development facility.

6.1 DEVELOPMENT MODEL FACILITIES

The SSFF Development Model will be housed in an existing facility. This area is in a building that includes offices, conference rooms, and development laboratories that can be used to support design and construction of the system.

The Development model ~~electrical hardware~~ and software will be developed in the Teledyne Brown Engineering Space Programs Avionics and Software Development Laboratory located in building 3 on the second floor. Existing laboratory space will be utilized and shared with other projects currently under development. The mechanical hardware will be developed in the SSFF designated laboratory on the first floor of building 3. The SSFF development model will be integrated and tested in the first floor SSFF laboratory. Figure 6.1-1 shows the SSFF laboratory facility floor plan.

Figure 6.1-1 shows the planned layout for the Development Model facility. The layout includes the major assemblies that make up the development model and the supporting laboratory furnishings and equipment. Locations of utility services (phones, water, electrical outlets, power) are also shown. the laboratory has a large roll-up door that will allow access for large assemblies and equipment. Several work areas are shown for fabrication and test of hardware components and assemblies. The area is also designed to support hardware and software integration testing.

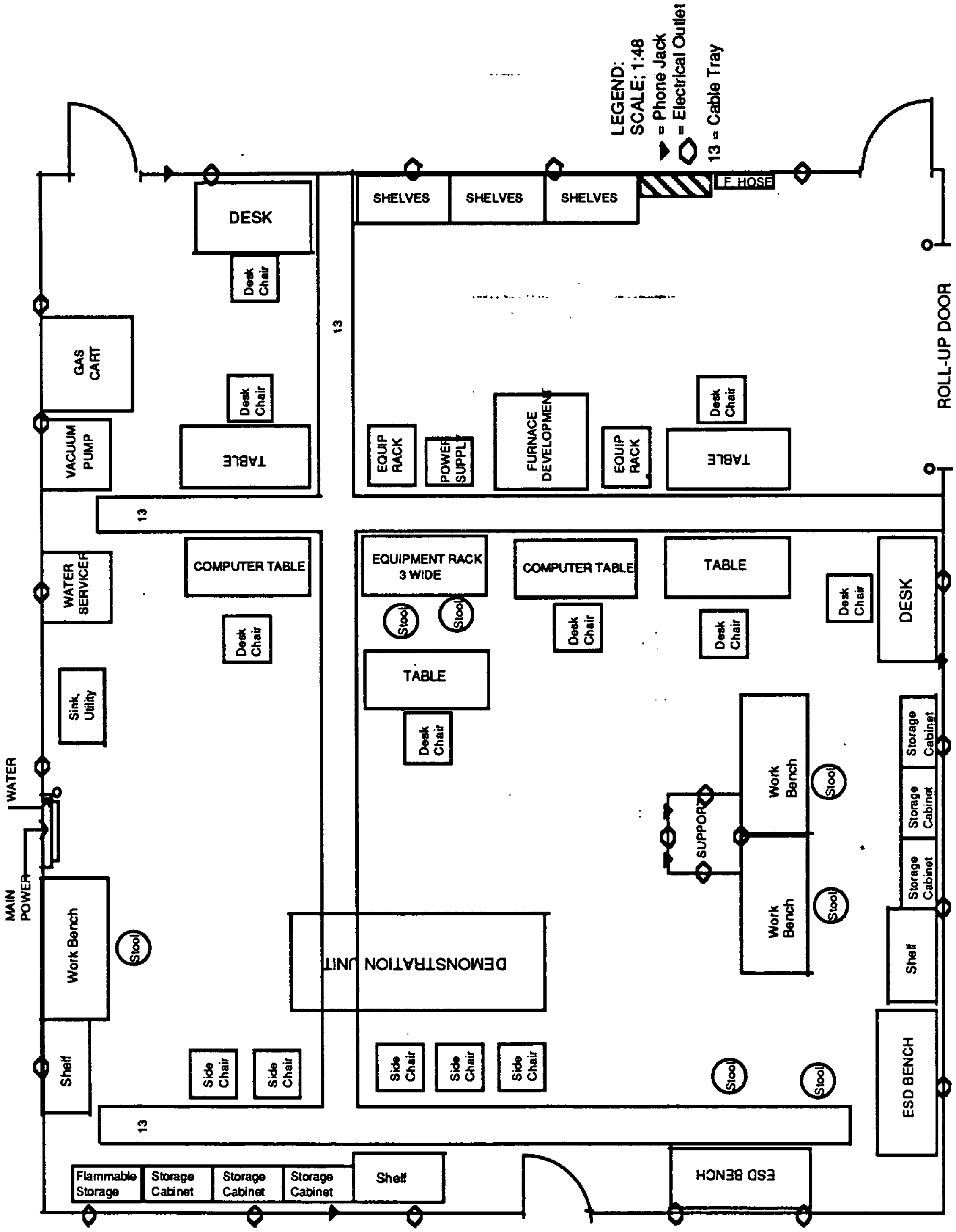

Figure 6.1-1 SSFF Development Model Facilities

6.2 DEVELOPMENT AND SUPPORT TOOLS

The development and support tools required for hardware and software development are summarized in Tables 6.2-1 and 6.2-2, respectively.

Table 6.2-1 Software Development Tools

Software for Code Development	Compilers, Assemblers, Linkers Editors Multi-tasking Operating Systems ~~Screen I/O Support~~ Software Graphics Support Software Communications Support Software
Software for Data Development	Database Management Software
Equipment for Code & Data Development	Development Computers Printers & Plotter Tape Backup Unit Communication Ports & Links

Table 6.2-2 Hardware Development Tools

General Laboratory Equipment	Soldering tools, scopes, meters, power supplies
General Tools	Screwdrivers, wrenches, drills
Special Purpose Tools	Tools for Connector Assembly
Calibration Equipment	Gas pressure transducer calibration equipment, gas flow rotameters
Test Fixtures/Equipment	Break-out boxes, vacuum leak detection equipment
Furnace Preparation/Integration	Thermocouple calibration test system. Thermocouple simulator

APPENDIX A: ABBREVIATIONS AND ACRONYMS

ADS	Application Dependent Software
AIS	Application Independent Software
CCU	Core Control Unit
CFS	Core Facility Services
CGF	Crystal Growth Furnace
CMC-SC	Core Montitor and Control - Signal Conditioner
CoDR	Conceptual Design Review
COREDACS	Core Data Acquisition and Control Software
CPC	Core Power Conditioner
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
CSS	Core Facility Support Software
DMS	Data Management Subsystem
EAC	Experiment Apparatus Container
FCU	Furnace Control Unit
FEP	Furnace Experiment Package
FHS	Furnace Heating System
GDS	Gas Distribution Subsystem
GN2	Gaseous Nitrogen
GSS	Ground Support Services
PC	Personal Computer
PCDS	Power Conditioning and Distribution Subsystem
PMZF	Programmable Multi-zone Furnace
PRV	Pressure Relief Valve
psi	Pounds/Square Inch
RAM	Random Access Memory
SCS	Signal Conditioning Subsystem
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To Be Determined
TCS	Thermal Control Subsystem
USL	United States Laboratory
Vac	Volts Alternating Current
Vdc	Volts Direct Current

APPENDIX B: FUNCTIONS VS DESIGN CROSS-REFERENCE

Functions		Design	
3.2.2	Ground Support Services Model	N/A	
3.2.1.1	Command and Display	3.3.1.1 3.3.1.2	DMS Interfaces GSS Computer Model
3.2.1.2	Database Maintenance	3.3.1.1 3.3.1.2	DMS Interfaces GSS Computer Model
3.2.2	SSF Services Model	N/A	
3.2.2.1	DMS Communications Link	3.3.1.1	DMS Interfaces
3.2.2.2	Power Services	3.3.2.1	SSF Power Services Model
3.2.2.3	Gas and Vacuum Services	3.3.4.1	SSF GDS Services Model
3.2.2.4	Thermal Control Services	3.3.5.1	SSF TCS Services Model
3.2.3	SSFF Core Facility Services Model	N/A	
3.2.3.1	Command and Data Management	3.3.1.1 3.3.1.3	DMS Interfaces SSFF CFS CCU Model
3.2.3.2	Subsystem Control	3.3.1.1 3.3.1.3 3.3.2.2 3.3.2.3 3.3.3 3.3.4.2 3.3.5.2	DMS Interfaces SSFF CFS CCU Model SSFF CFS CPD Model SSFF CFS CPC Model SSFF CFS CMC-SC Model SSFF CFS GDS Model SSFF CFS TCS Model
3.2.3.3	Power Distribution	3.3.2.2	SSFF CFS CPD Model
3.2.3.4	Power Conditioning	3.3.2.3	SSFF CFS CPC Model
3.2.3.5	Signal Conditioning	3.3.3	SSFF CFS SCS Model
3.2.3.6	Gas Distribution	3.3.4.2	SSFF CFS GDS Model
3.2.3.7	Thermal Control	3.3.5.2	SSFF CFS TCS Model
3.2.4	SSFF Furnace Experiment Package Model	N/A	
3.2.4.1	Remote Sensor Acquisition	3.3.1.1 3.3.1.4	DMS Interfaces SSFF FEP FCU Model
3.2.4.2	Furnace Heating System Functions	3.3.1.5	SSFF FEP Heater Load and Temperature Model
3.2.4.3	Thermal and Gas Interface and Characteristics	3.3.4.3 3.3.5.3	SSFF FEP EAC Model SSFF FEP Heater Model

SF-TP-0001

DEMONSTRATION TEST PLAN

FOR THE

SPACE STATION FURNACE FACILITY DEVELOPMENT MODEL

May 1992

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1. INTRODUCTION

The Space Station Furnace Facility (SSFF) is a microgravity materials processing experiment facility. It is scheduled for installation and operation in the United States Laboratory (USL) Module of the Space Station Freedom (SSF). It is designed for microgravity materials research in metals, oxides, glasses, and alloy solidification and crystal growth of electronic and electro-optical materials.

The SSFF Development Model is designed to demonstrate the feasibility of the SSFF concept. It models the functions and physical interfaces of the SSFF including the Space Station services and the furnace modules.

1.1 IDENTIFICATION

This document is the SSFF Development Model Demonstration Test Plan. This test plan defines the strategy and methodology for each Demonstration Test.

1.2 PURPOSE

The purpose of this document is to define the test descriptions and procedures for the SSFF Development Model Demonstration Tests. These tests will show that the SSFF concept is feasible through demonstration testing of operational and functional capabilities. The Demonstration Tests are structured to show that the Development Model meets the requirements of the SSFF contract Statement of Work (SOW):

Contract SOW Paragraph - 5.3 Development Models Design, Fabrication, Assembly and Test

"The contractor shall design, fabricate, assemble, and test a development model of the core facility to demonstrate the feasibility of the design concept selected. The development model shall be designed to provide high-fidelity physical and functional interfaces with the experiment modules and Space Station interfaces to the extent that they are defined. Commercial grade parts and equipment will be acceptable for control and data acquisition systems, thermal control and other support systems. The development model shall be designed so that it can be configured to operate each type of furnace for selected '"strawman" experiments. Operation of all types of furnaces in parallel is not required; however, parallel operation of the furnace modules in the USL shall be considered and the core facility development model shall be used to demonstrate this capability. Demonstration tests shall be conducted to demonstrate operations in the man-tended and fully manned modes."

An overview of how the plan for the Demonstration Tests meets these requirements is given below.

1) "...demonstrate the feasibility of the design concept selected."

The Demonstration Tests are designed to show that the design concept is feasible by performance of operational functions in the integrated Development Model system. The system provides a Core Facility, two furnace models, and a model of the Space Station services. This design is based on the SSFF Conceptual Design Review (CoDR) concept and the changes incorporated due to Space Station restructuring. The performance and functions are based on information contained in the Capabilities and Science Requirements Document.

2) "...provide high-fidelity physical and functional interfaces with the experiment modules and Space Station interfaces to the extent that they are defined."

The Demonstration Tests are designed to show that the functional interfaces with the experiment modules and the SSF exhibit high-fidelity operation in the integrated system.

3) "...designed so that it can be configured to operate each type of furnace for selected 'strawman' experiments."

The Demonstration Tests are designed to show functional operation of the SSFF with four different configurations of furnaces. The first configuration, Type 1, is a load module simulation of furnace heater elements configured with the characteristics of a Crystal Growth Furnace (CGF). The second configuration, Type 2, is another load module simulation configured with the characteristics of a Transparent furnace. The final two configurations are a Space Science Laboratory (SSL) furnace and a Transparent furnace.

4) "...parallel operation of the furnace modules in the USL shall be considered and the core facility development model shall be used to demonstrate this capability"

The Demonstration Test Plan includes demonstration testing to meet these objectives. The definition of these tests are documented in separate appendices of this document. Operation of the SSFF Development Model will be demonstrated using three different

combinations of load modules and furnaces. Each combination will include two operational units. For each combination, the modules and/or furnaces will be operated in parallel using timelines defined for the demonstration, including staggered timeline operation to meet power constraints.

5) "Demonstration tests shall be conducted to demonstrate operations in the man-tended and fully manned modes."

The Demonstration Test Plan includes demonstration testing to meet these objectives. Since the fully manned activities are a subset of the man-tended activities, the operational scenarios are defined to demonstrate the man-tended mode which is the most demanding.

1.3 SCOPE

This document defines the procedures for the SSFF Development Model Demonstration Tests which are comprised of three separate tests. The first demonstration test will be performed using two load modules, Type 1 and Type 2 furnaces. The second demonstration test will be performed using one load module in Type 2 furnace configuration and an SSL furnace. The third demonstration test will be performed using an SSL furnace and a Transparent furnace. Hardware and software configurations for each demonstration test, pretest and test inputs, and test outputs are specified in this document. The demonstration test procedures and test evaluation are also provided.

1.4 ORGANIZATION

This test plan is organized into three major sections, plus four appendices. Section 1 is a brief introduction. Section 2 lists the documents applicable to this test plan. Section 3 defines the test description. Appendix A lists the abbreviations and acronyms. Appendix B defines the test procedures for the two load modules, Type 1 and Type 2 furnaces, demonstration test. Appendix C defines the test procedures for the one load module in Type 2 furnace configuration and an SSL furnace demonstration test. Appendix D defines the test procedures for the SSL furnace and Transparent furnace demonstration test. The appendices are included as each test is performed.

1.5 LIMITATIONS

This is a demonstration of the functional capabilities of the development model and is not a formal test.

2. APPLICABLE DOCUMENTS

The following documents provide additional information and references which are applicable to the Demonstration Test effort.

Number	Name or Description
JA55-032	Space Station Furnace Facility Science Requirements Document
	Development Plan For The Space Station Furnace Facility Development Model

3. DEMONSTRATION TEST DESCRIPTION

3.1 FACILITIES

The SSFF Development Model Demonstration Tests will be held in the SSFF Development Model Laboratory at Building 3 of Teledyne Brown Engineering (TBE).

3.2 EQUIPMENT

The SSFF Development Model Demonstration Tests will utilize the following:

- The SSFF Core Facility Services Model which includes:
  - Command and Data Management
  - Subsystem Control
  - Power Distribution
  - Power Conditioning
  - Signal Conditioning
  - Gas Distribution
  - Thermal Control
- Two Load Modules
- Two Gas and Thermal Interface Characteristic Models
- One SSL Furnace
- One Transparent Furnace
- The SSF Services Model which includes:
  - Water Servicer
  - Vacuum System
  - Gas System
  - Power and Communications Interfaces
- The SSFF Ground Support Services (GSS) Computer Model which includes:
  - Commanding
  - Telemetry
  - Graphics

The SSFF Development Model Demonstration Tests will also utilize other test equipment as called out in the demonstration test procedures.

3.3 PERSONNEL

The SSFF Development Model Demonstration Test team will include members from the Test, Systems Engineering, Software Development, Avionics, and Mechanical functional areas.

3.4 METHODOLOGY

The demonstration tests will be performed in accordance with the procedures included in the appendices. These procedures are not formal and are meant to be executed by personnel familiar with the SSFF development model. If procedural errors are discovered during the demonstration tests, red-lines will be made to the procedures.

3.5 DATABASES

Furnace Heating System (FHS) and Environmental Control System (ECS) timeline databases will be defined for the demonstration tests. These timelines will be built and converted, then loaded into the Command Computer prior to each demonstration test.

APPENDIX A: ABBREVIATIONS AND ACRONYMS

The following is a list of the abbreviations and acronyms used in this specification.

CGF	-	Crystal Growth Furnace
CoDR	-	Conceptual Design Review
ECS	-	Environmental Control System
FHS	-	Furnace Heating System
GSS	-	Ground Support Services
SOW	-	Statement Of Work
SSF	-	Space Station Freedom
SSFF	-	Space Station Furnace Facility
SSL	-	Space Science Laboratory
TBE	-	Teledyne Brown Engineering
USL	-	United States Laboratory

APPENDIX B

SSFF LOAD MODULES DEMONSTRATION TEST

SSFF LOAD MODULES DEMONSTRATION TEST

1.0 OBJECTIVE

The objective of this demonstration test is to demonstrate the capability to operate two load modules, Type 1 and Type 2 furnaces, in parallel and under nominal conditions.

2.0 TEST CONFIGURATION

The configuration for this demonstration test will include the SSFF Core Facility Services Model; two furnace models, one configured to model a Type 1 furnace and one configured to model a Type 2 furnace; the SSF Services Model; and the GSS Computer Model. This configuration is shown in Figure B-1.

3.0 PRE-DEMONSTRATION TEST INPUTS

Prior to the demonstration test, the temperature and pressure timelines for this test will be loaded into the SSFF directory on the Command Computer. Figures B-2 through B-5 contain the timeline definitions.

4.0 DEMONSTRATION TEST INPUTS

1) Automatic processing commands
2) Telemetry log file names
3) Screen selections on the telemetry and graphics computers.

5.0 EXPECTED OUTPUTS

The following outputs will be to the telemetry and graphics computers:

1) Furnace temperature tracking data to the telemetry and graphics computers
2) Furnace temperature stability data to the telemetry and graphics computers
3) Furnace temperature ramp rate data to the telemetry computer
4) Pressure data to the telemetry computer
5) Water temperature data to the telemetry computer
6) Gas and water flow rate data to the telemetry computer
7) Heater data (current, voltage, power) to the telemetry and graphics computers

6.0 DEMONSTRATION TEST PROCEDURE

Table B contains the detailed test procedure for the SSFF Load Modules Demonstration Test.

7.0 TEST EVALUATION

The output data will be evaluated against the database timelines. This evaluation includes the data output to the telemetry and graphics screens and the data logged by the telemetry computer during the demonstration test.

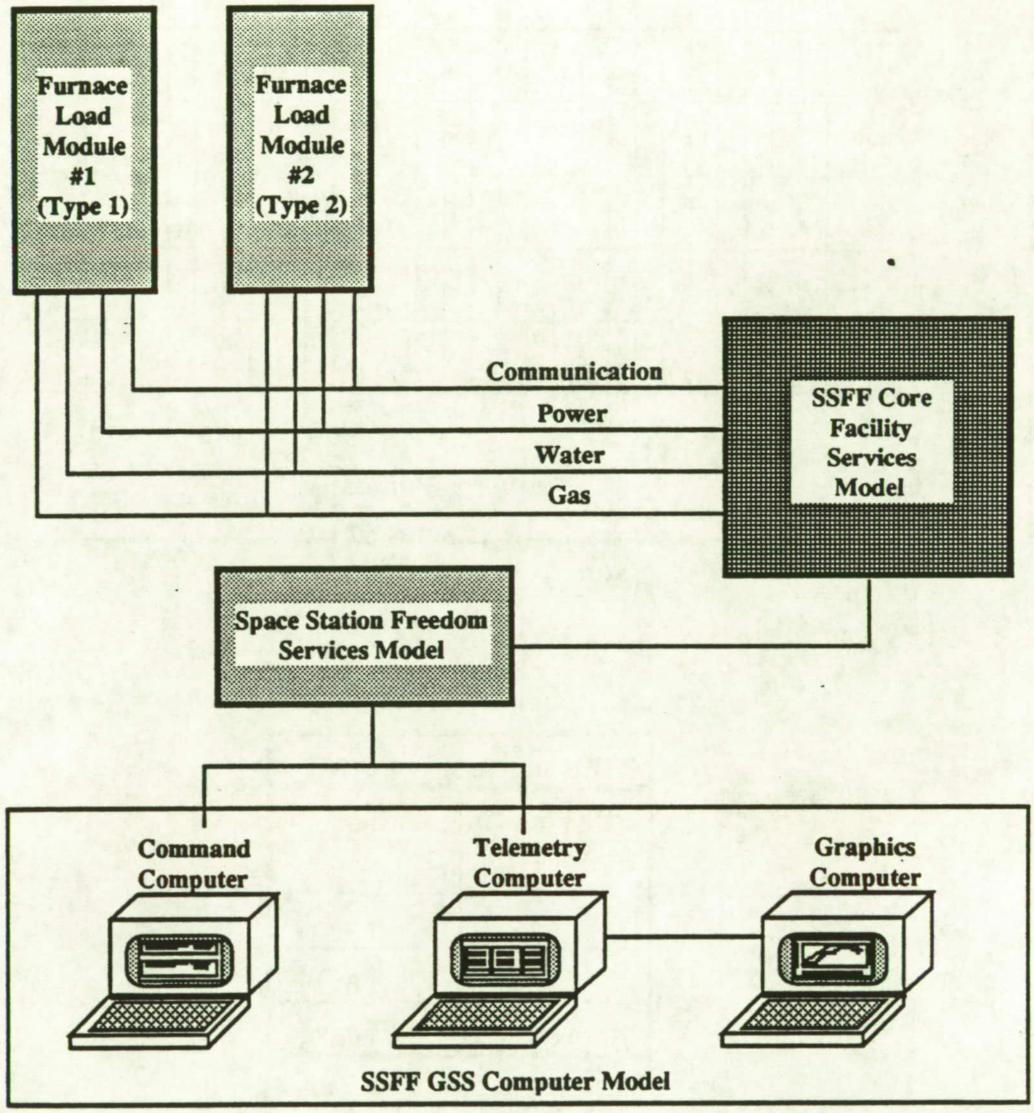
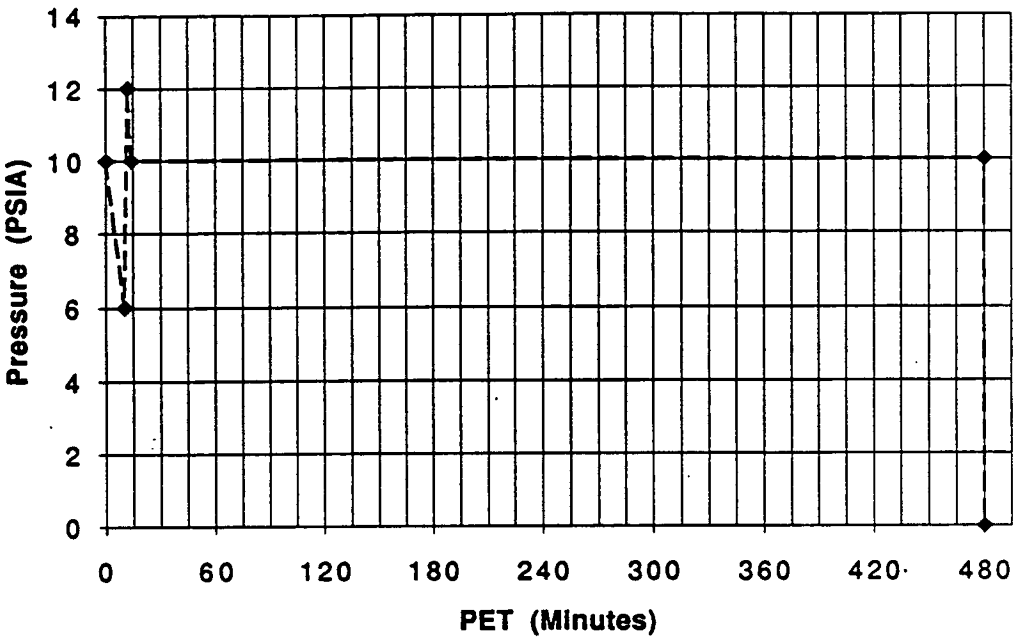


Figure B-1 SSFF Load Modules Demonstration Test Configuration



PET Minutes	PSIA
0	10
10	6
12	12
14	10
480	10

Figure B-2 Environmental Control System Timeline

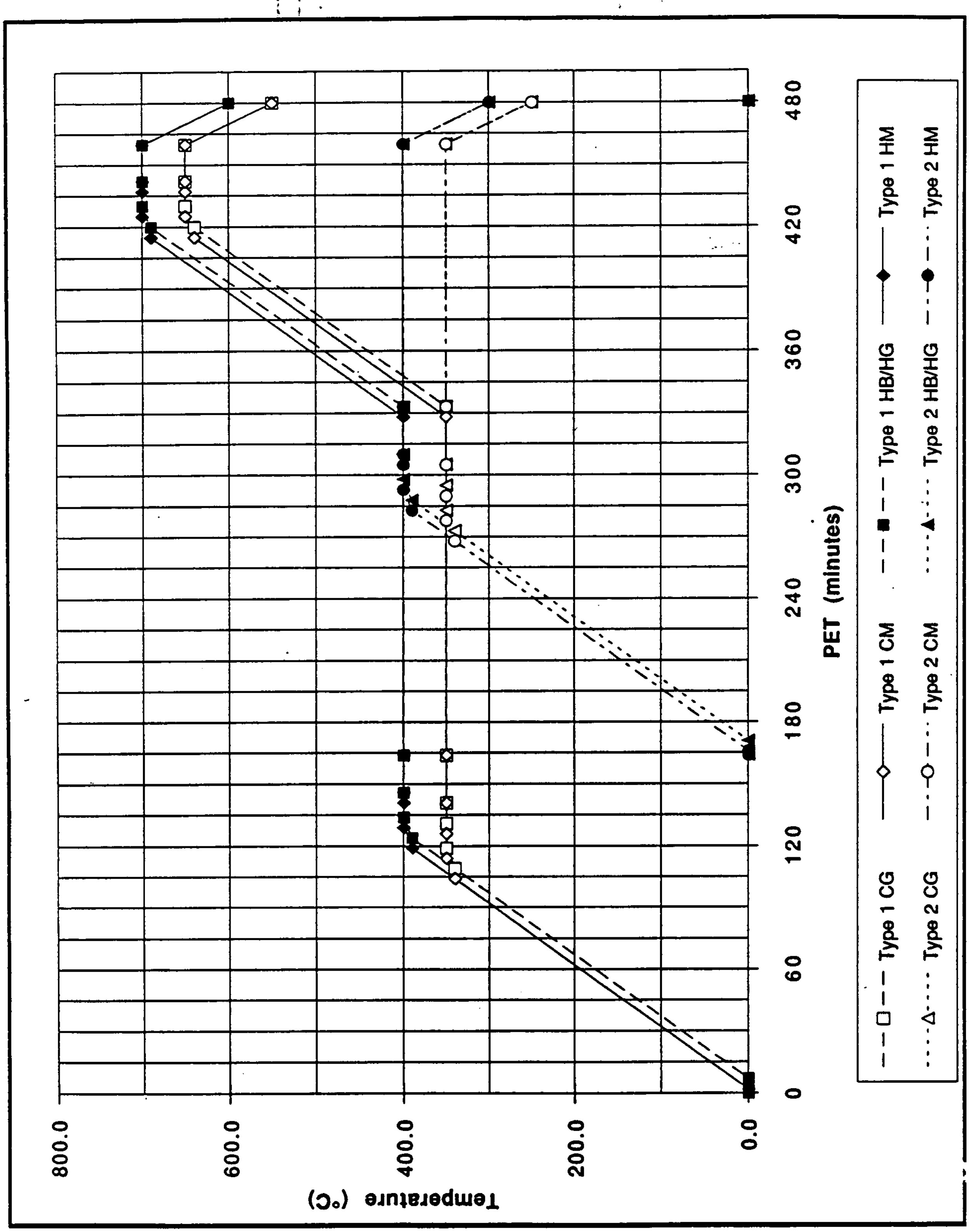
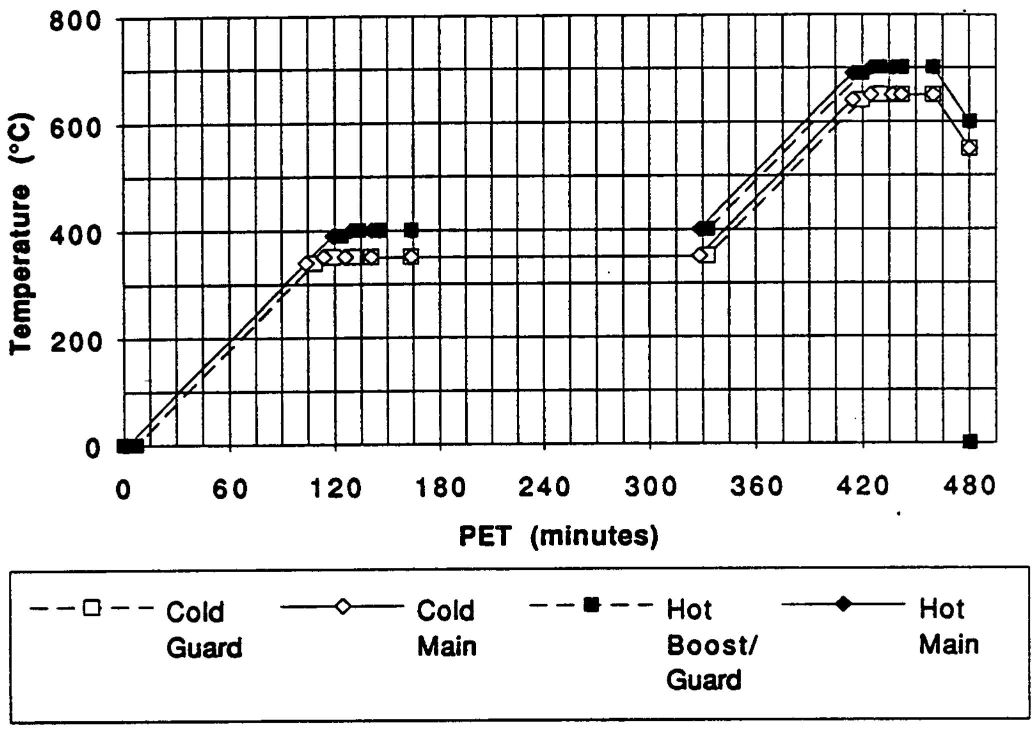
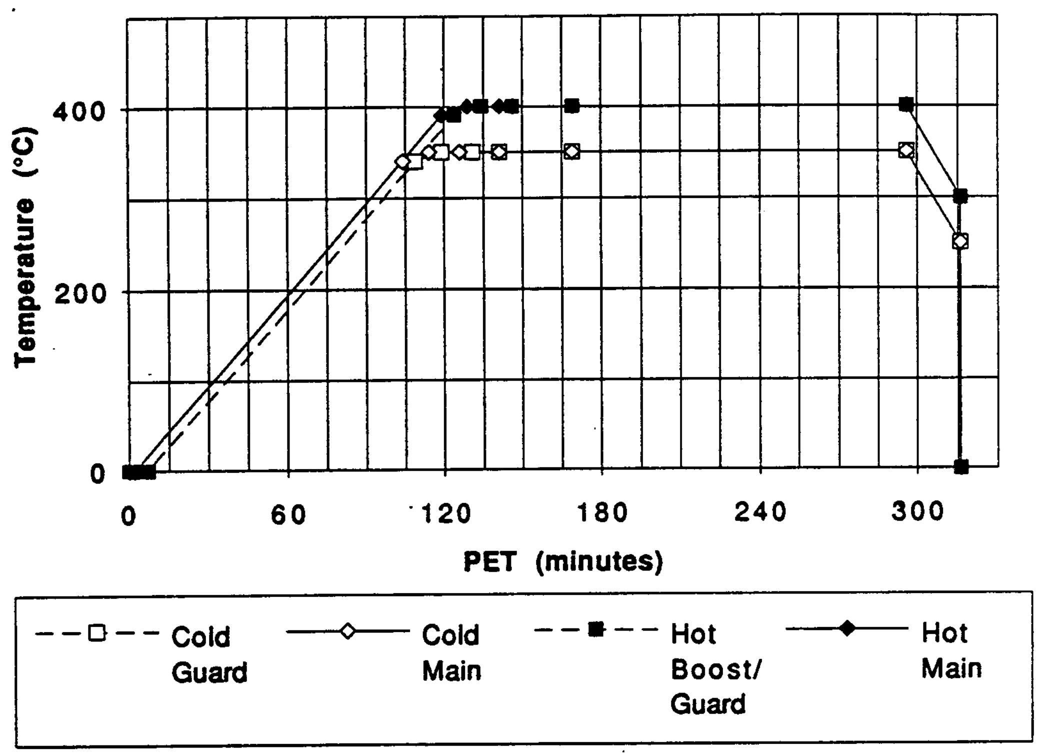


Figure B-3 Furnace Heating System Timeline for Type 1 and Type 2 Furnace Demonstration



Cold Guard		Cold Main		Hot Boost/Guard		Hot Main	
Minutes	**°C**	**Minutes**	**°C**	**Minutes**	**°C**	**Minutes**	**°C**
0	0	0	0	0	0	0	0
2	0	2	0	2	0	2	0
7	0	104	340	7	0	119	390
109	340	114	350	124	390	129	400
119	350	126	350	134	400	141	400
131	350	141	350	146	400	146	400
141	350	164	350	164	400	164	400
164	350	328	350	333	400	328	400
333	350	415	640	420	690	415	690
420	640	425	650	430	700	425	700
430	650	437	650	442	700	437	700
442	650	442	650	460	700	442	700
460	650	460	650	480	600	460	700
480	550	480	550	480	0	480	600
480	0	480	0			480	0

Figure B-4 Furnace Heating System Profile and Timeline for Type 1 Furnace



Cold Guard		Cold Main		Hot Boost/Guard		Hot Main	
Minutes	°C	Minutes	°C	Minutes	°C	Minutes	°C
0	0	0	0	0	0	0	0
2	0	2	0	2	0	2	0
7	0	104	340	7	0	119	390
109	340	114	350	124	390	129	400
119	350	126	350	134	400	141	400
131	350	141	350	146	400	146	400
141	350	169	350	169	400	169	400
169	350	296	350	296	400	296	400
296	350	316	250	316	300	316	300
316	250	316	0	316	0	316	0
316	0						

Figure B-5 Furnace Heating System Profile and Timeline for Type 2 Furnace

TABLE B1
SSFF LOAD MODULES DEMONSTRATION TEST PROCEDURE

Step No.	Operator/Equipment Action	Expected Response	Evaluation Criteria	Criteria Met
1	At the Telemetry Computer, enter the following from Screen 6 to initiate logging: <F3>DEMOLM1.LOG<Enter> **NOTE:** For delogging purposes, a new log file will be created at the times indicated by entering: <F5>new log name<F10>	"Logging on." is displayed at the lower right corner.	Exact	______
2	At the Command Computer, enter the following to begin Sample 1 processing for Furnace 1: C 1<F10> 1<F10> 1<F10> **NOTE:** Create new log files: DEMOLM2.LOG @ **5700** Furnace 1 PET seconds DEMOLM3.LOG @ **9300** Furnace 1 PET seconds	At the appropriate Telemetry Computer screens for Furnace 1:		
		1. At **140** PET seconds, COLD MAIN and HOT MAIN heater zones begin to heat as shown in Figure B-4.	1. Exact	______
		2. At **440** PET seconds,COLD GUARD, BOOSTER, AND HOT GUARD heater zones begin to heat as shown in Figure B-4.	2. Exact	______
		3. At **600** PET seconds, F1 PRES decreases to 6 psia.	3. Exact	______
		4. At **720** PET seconds, F1 PRES increases to 12 psia.	4. Exact	______
		5. At **840** PET seconds, F1 PRES decreases to 10 psia and holds until test completion.	5. Exact	______
		6. By **8040** PET seconds, timeline-defined set point temperatures will be displayed by all heater zones; by **8760** PET seconds, actual temperatures for all heater zones correspond to the set points displayed and holds until **19980** PET seconds.	6. Exact	______

TABLE B1
SSFF LOAD MODULES DEMONSTRATION TEST PROCEDURE

Step No.	Operator/Equipment Action	Expected Response	Evaluation Criteria	Criteria Met
3	When PET seconds for Furnace 1 reaches **9840**, enter the following at the Command Computer to begin Sample 2 processing for Furnace 2: 1<F10> 2<F10> 2<F10> **NOTE:** Create new log files: DEMOLM4.LOG @ **15600** Furnace 1 PET seconds DEMOLM5.LOG @ **19200** Furnace 1 PET seconds	At the appropriate Telemetry Computer screens for Furnace 2:		
		1. At 140 PET seconds, COLD MAIN and HOT MAIN heater zones begin to heat as shown in Figure B-5.	1. Exact	______
		2. At 440 PET seconds,COLD GUARD, BOOSTER, AND HOT GUARD heater zones begin to heat as shown in Figure B-5.	2. Exact	______
		3. By **8040** PET seconds, timeline-defined set point temperatures will be displayed by all heater zones; by **8760** PET seconds, actual temperatures for all heater zones correspond to the set points displayed and will hold until PET seconds displays **17460**.	3. Exact	______
4	Toggle between the appropriate screens for Furnace 1 and Furnace 2 at the Telemetry Computer. **NOTE:** Create a new log file: DEMOLM6.LOG @ **24300** Furnace 1 PET seconds	1. At **19680** PET seconds, Furnace 1 COLD MAIN and HOT MAIN heater zones begin to heat as shown in Figure B-4.	1. Exact	______
		2. At **19980** PET seconds, Furnace 1 COLD GUARD, BOOSTER, AND HOT GUARD heater zones begin to heat as shown in Figure B-4.	2. Exact	______
		3. By **25800** PET seconds, timeline-defined set point temperatures will be displayed by all Furnace 1 heater zones; by **26520** PET seconds, actual temperatures for all Furnace 1 heater zones correspond to the set points displayed and will hold until PET seconds displays **27600**, at which point it begins to cool.	3. Exact	______
		4. At Screen 11, when Furnace 2 reached **17640** PET seconds, it began to cool.	4. Exact	______
5	At the Telemetry Computer, observe Screen 1 when Furnace 1 PET seconds displays **28800** and Furnace 2 PET seconds displays **18960.**	System State displays "Manual".	Exact	______
6	At the Telemetry Computer, enter the following to turn of data logging: <F4>	"Logging off." is displayed.	Exact	______

APPENDIX C

SSFF SSL FURNACE AND LOAD MODULE DEMONSTRATION TEST

SSFF SSL FURNACE AND LOAD MODULE DEMONSTRATION TEST

1.0 OBJECTIVE

The objective of this demonstration test is to demonstrate the capability of parallel operation of an SSL furnace under vacuum and a load module, Type 2 furnace, with a real-time off-nominal condition.

2.0 TEST CONFIGURATION

The configuration for this demonstration test will include the SSFF Core Facility Services Model; an SSL furnace; one furnace model, configured to model a Type 2 furnace; the SSF Services Model; and the GSS Computer Model. This configuration is shown in Figure C-1.

3.0 PRE-DEMONSTRATION TEST INPUTS

Prior to the demonstration test, the temperature and pressure timelines for this test will be loaded into the SSFF directory on the Command Computer. Figures C-2 through C-5 contain the timeline definitions.

4.0 DEMONSTRATION TEST INPUTS

1) Automatic processing commands
2) To disconnect the power module to the cold main heater for the load module
3) Telemetry log file names
4) Screen selections on the telemetry and graphics computers.

5.0 EXPECTED OUTPUTS

The following outputs will be to the telemetry and graphics computers:

1) Furnace temperature tracking data to the telemetry and graphics computers
2) Furnace temperature stability data to the telemetry and graphics computers
3) Furnace temperature ramp rate data to the telemetry computer
4) Pressure data to the telemetry computer
5) Water temperature data to the telemetry computer
6) Gas and water flow rate data to the telemetry computer
7) Heater data (current, voltage, power) to the telemetry and graphics computers

6.0 DEMONSTRATION TEST PROCEDURE

Table C contains the detailed test procedure for the SSFF SSL Furnace and Load Module Demonstration Test.

7.0 <u>TEST EVALUATION</u>

The output data will be evaluated against the database timelines. This evaluation includes the data output to the telemetry and graphics screens and the data logged by the telemetry computer during the demonstration test. The power readings for the load module cold main heater will be checked to verify a redundant power module started when the power failure was induced.

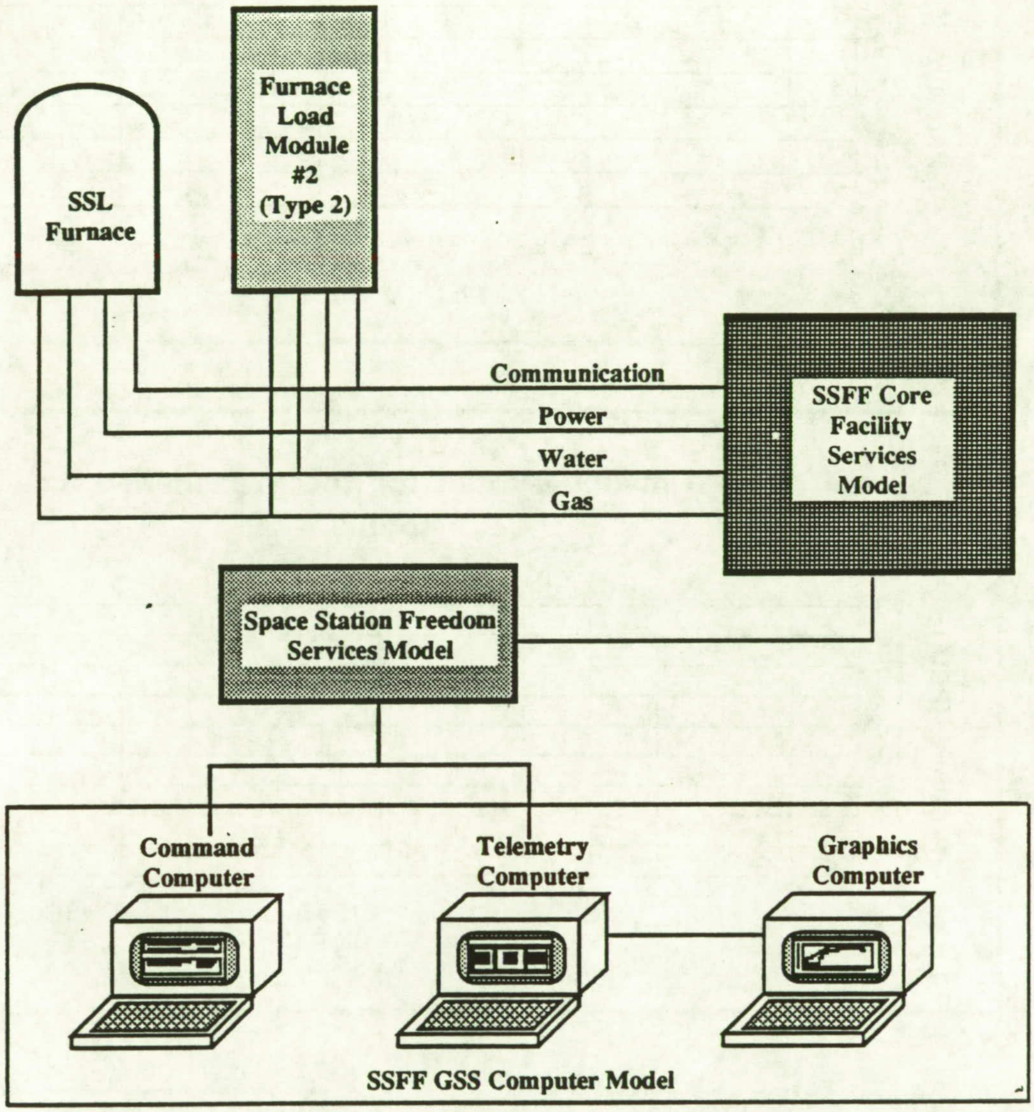
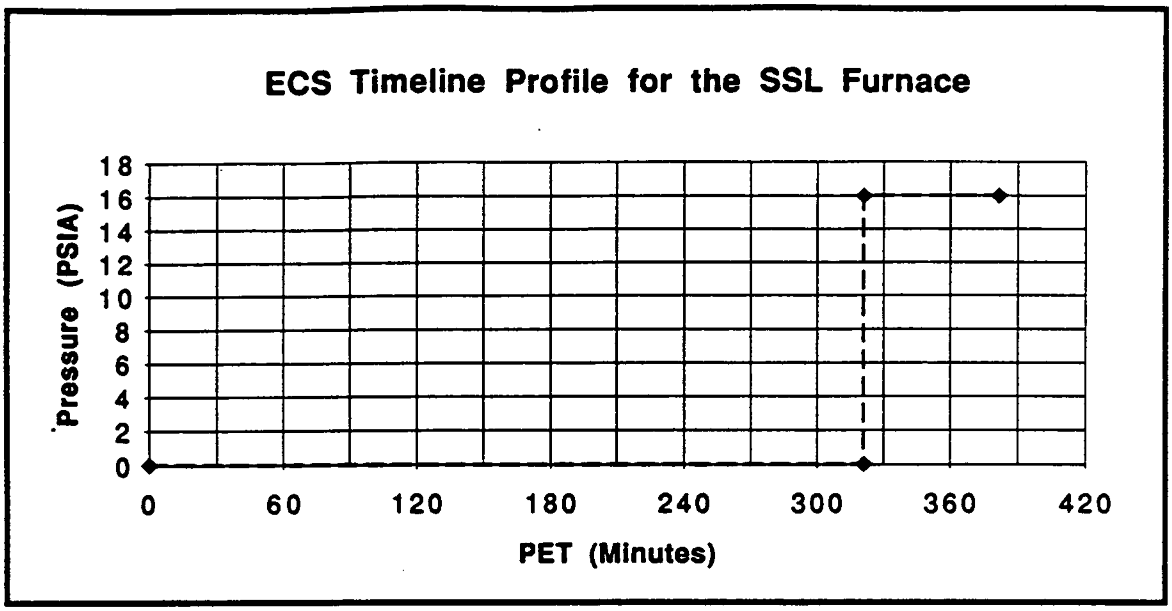
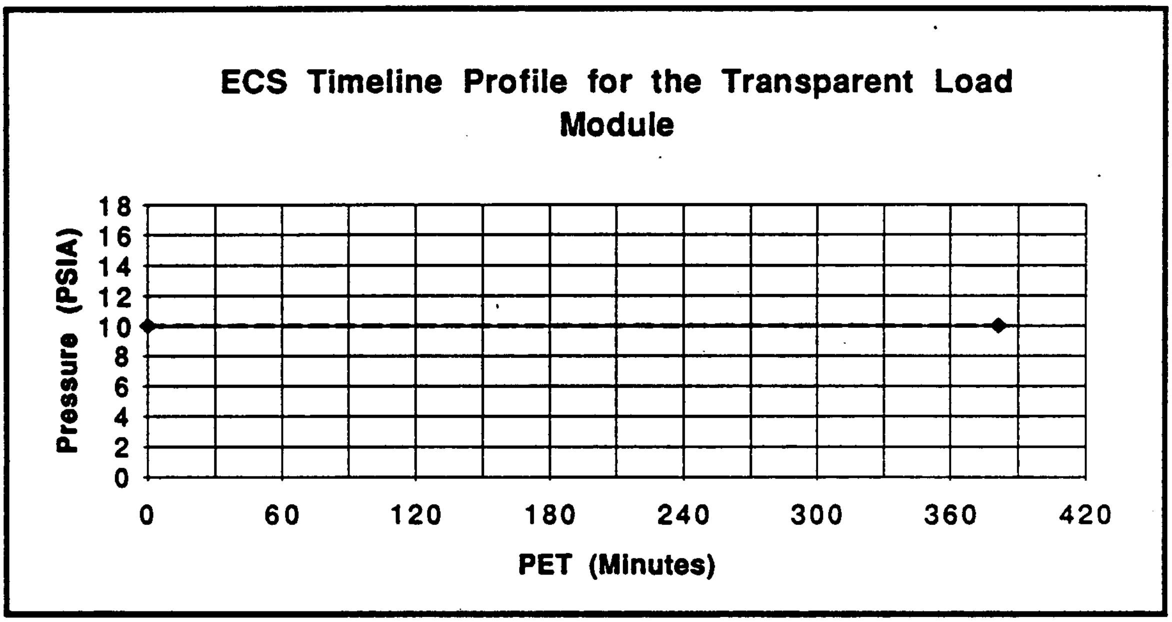


Figure C-1 SSFF SSL Furnace and Load Module Demonstration Test Configuration





SSL Furnace	
PET Minutes	PSIA
0	0
320.9	16
381.4	16

Type 2 Load Module	
PET Minutes	PSIA
0	10
381.4	10

Figure C-2 Environmental Control System Timeline

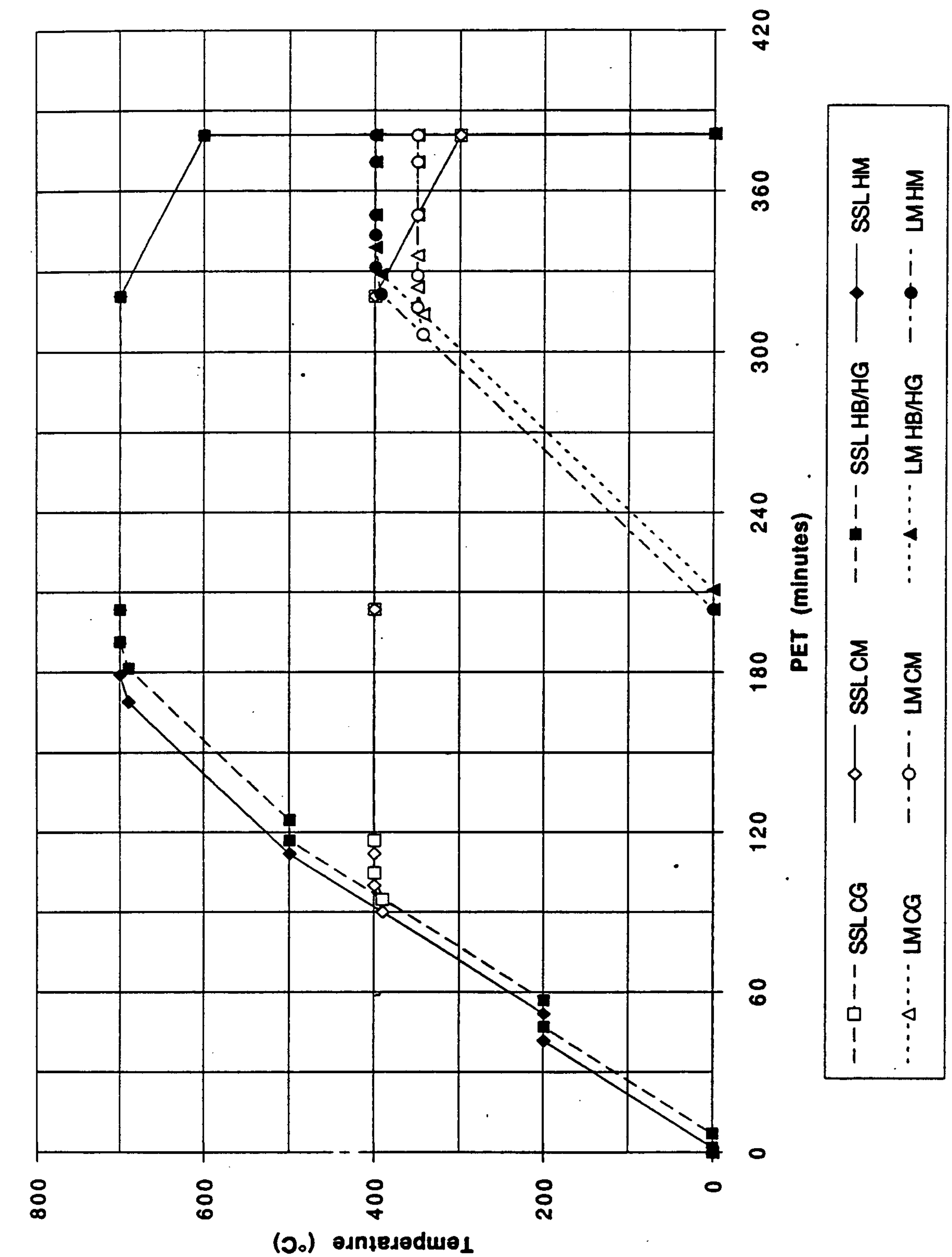
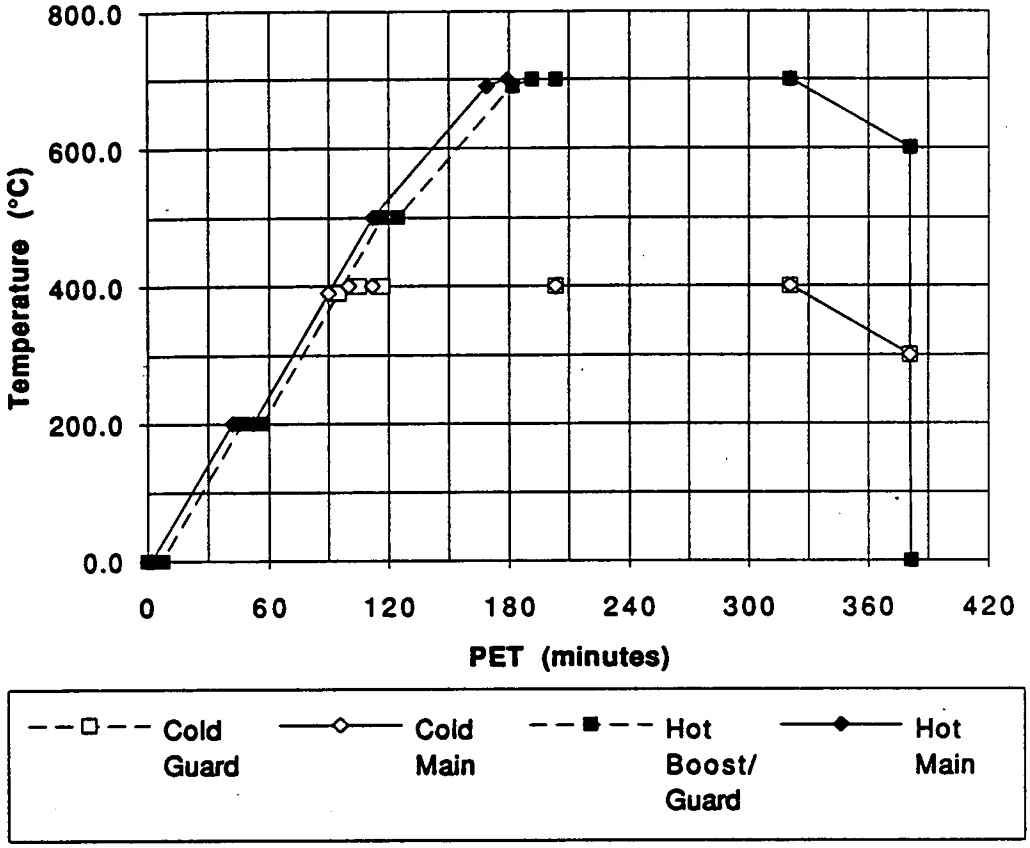
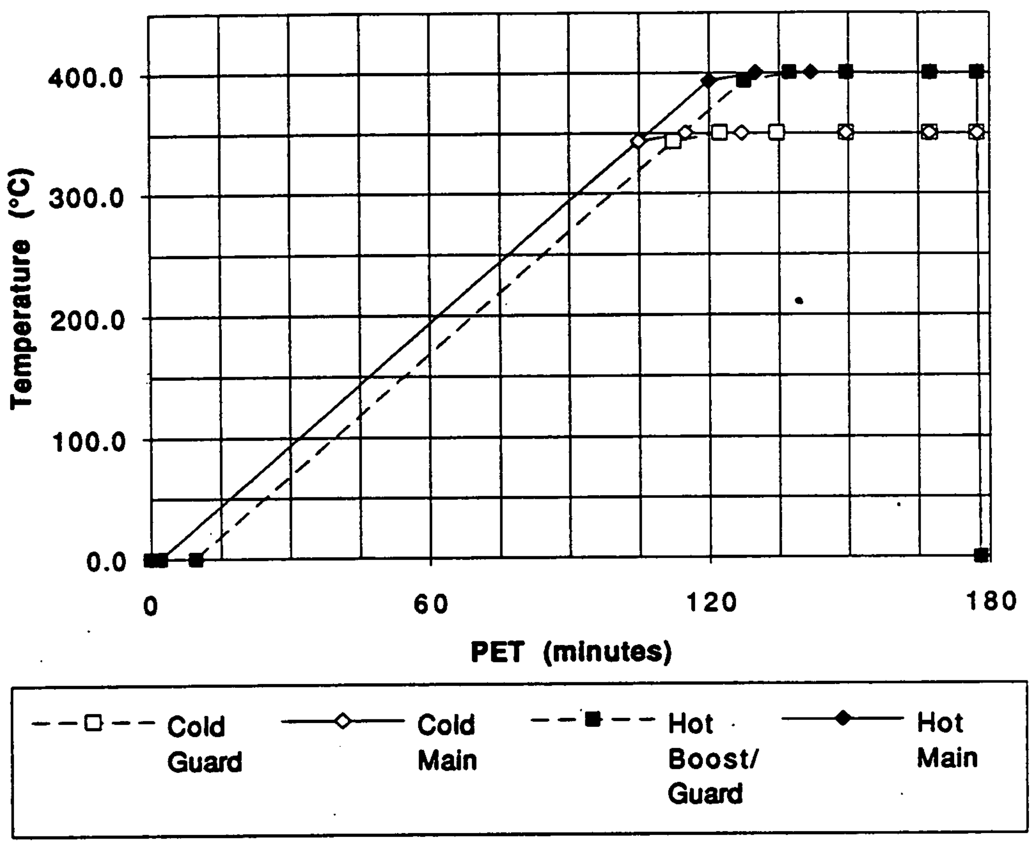


Figure C-3 Furnace Heating System Timeline Profile for SSL Furnace and Load Module Demonstration Test



Cold Guard		Cold Main		Hot Boost/Guard		Hot Main	
Minutes	°C	Minutes	°C	Minutes	°C	Minutes	°C
0.0	0	0.0	0	0.0	0	0.0	0
2.0	0	2.0	0	2.0	0	2.0	0
7.0	0	42.0	200	7.0	0	42.0	200
47.0	200	52.0	200	47.0	200	52.0	200
57.0	200	90.0	390	57.0	200	112.0	500
95.0	390	100.0	400	117.0	500	169.0	690
105.0	400	112.0	400	124.5	500	179.0	700
117.0	400	203.5	400	181.5	690	191.0	700
203.5	400	320.9	400	191.5	700	203.5	700
320.9	400	380.9	300	203.5	700	320.9	700
380.9	300	381.4	0	320.9	700	380.9	600
381.4	0			380.9	600	381.4	0
				381.4	0		

Figure C-4 Furnace Heating System Profile and Timeline for SSL Furnace



Cold Guard		Cold Main		Hot Boost/Guard		Hot Main	
Minutes	°C	Minutes	°C	Minutes	°C	Minutes	°C
0.0	0	0.0	0	0.0	0	0.0	0
2.0	0	2.0	0	2.0	0	2.0	0
9.5	0	104.9	343	9.5	0	119.9	393
112.4	343	114.9	350	127.4	393	129.9	400
122.4	350	126.9	350	137.4	400	141.9	400
134.4	350	149.4	350	149.4	400	149.4	400
149.4	350	167.4	350	167.4	400	167.4	400
167.4	350	177.4	350	177.4	400	177.4	400
177.4	350	177.9	0	177.9	0	177.9	0
177.9	0						

Figure C-5 Furnace Heating System Profile and Timeline for Type 2 Furnace

TABLE C1
SSFF SSL FURNACE AND LOAD MODULE DEMONSTRATION TEST PROCEDURE

Step No.	Operator/Equipment Action	Expected Response	Evaluation Criteria	Criteria Met
1	At the Telemetry Computer, enter the following from Screen 6 to initiate logging: <F3>DEMOSSL1.LOG<Enter> **NOTE:** For delogging purposes, a new log file will be created at the times indicated by entering: <F5>new log name<F10>	"Logging on." is displayed at the lower right corner.	Exact	______
2	At the Command Computer, enter the following to begin Sample 1 processing for the SSL Furnace: C 1<F10> 1<F10> 1<F10> **NOTE:** Create new log files: DEMOSSL2.LOG @ **5100** ___ SSL Furnace PET seconds DEMOSSL3.LOG @ **9840** ___ SSL Furnace PET seconds	At the Telemetry Computer: 1. At Screen 6, observe the F1 VENT valve status change to OPEN and the Furn 1 F1 PRES change to 0.0 PSIA.	1. Exact; ±1.5 psia	______
		2. At Screen 9, by **145** PET seconds, heater zones begin to heat as shown in Figure C-4.	2. Exact	______
		3. By **2830** PET seconds, timeline-defined set point temperature of 200°C is displayed by all heater zones.	3. Exact	______
		4. By **7020** PET seconds, actual temperatures for COLD GUARD and COLD MAIN heater zones correspond to the 400°C set points displayed.	4. Exact	______

TABLE C1
SSFF SSL FURNACE AND LOAD MODULE DEMONSTRATION TEST PROCEDURE

Step No.	Operator/Equipment Action	Expected Response	Evaluation Criteria	Criteria Met
3	When PET seconds for the SSLFurnace reaches **12200**, enter the following at the Command Computer to begin Sample 2 processing for Furnace 2: 1<F10> 2<F10> 2<F10> NOTE: Create new log files: DEMOLM4.LOG @ **14400** ___ SSL Furnace PET seconds DEMOLM5.LOG @ **18000** ___ SSL Furnace PET seconds	1. Actual temperatures for the SSL Furnace BOOSTER, HOT MAIN AND HOT GUARD heater zones correspond to the 700°C set points displayed.	1. Exact	_______
		2. At Screen 13, the reading for the Sample TC1 corresponds to the reading on Screen 19 of the Graphics Computer.	2. Exact	_______
		3. At Screen 6 of the Telemetry Computer, the Furn 1 F2 PRES corresponds to 10.0 PSIA.	3. Exact	_______
		4. At Screen 11, by **145** Furn 2 PET seconds, heater zones begin to heat as shown in Figure C-5.	4. Exact	_______
		5. By **8964** Furn 2 PET seconds, the actual temperatures for COLD GUARD and COLD MAIN heater zones correspond to the 350°C set points displayed and the actual temperatures for BOOSTER, HOT MAIN and HOT GUARD heater zones correspond to the 400°C set points displayed .	5. Exact	_______
		6. At Screen 9 of the Telemetry Computer and Screen 16 of the Graphics Computer, observe the cool down of the SSL Furnace.	6. Exact	_______
4	At Screen 19 of the Telemetry Computer, when Furnace 2 PET seconds reaches **10044**, remove F50 fuse from the Electrical Core Rack.	COLD MAIN 2 changes to 10.00 V and COLD MAIN 4 recovers the power loss of COLD MAIN 2.	Exact	_______
5	At the Telemetry Computer, observe Screen 1 when Furnace 1 PET seconds displays **22884** and Furnace 2 PET seconds displays **10674.**	System State displays "Manual".	Exact	_______
6	At the Telemetry Computer, enter the following to turn of data logging: <F4>	"Logging off." is displayed.	Exact	_______

APPENDIX D

SSFF SSL FURNACE AND TRANSPARENT FURNACE DEMONSTRATION TEST

SSFF SSL FURNACE AND TRANSPARENT FURNACE DEMONSTRATION TEST

1.0 OBJECTIVE

The objective of this demonstration test is to demonstrate the capability of parallel operation of an SSL furnace under vacuum and a Transparent furnace under ambient conditions.

2.0 TEST CONFIGURATION

The configuration for this demonstration test will include the SSFF Core Facility Services Model, an SSL furnace, a Transparent furnace, the SSF Services Model, and the GSS Computer Model. This configuration is shown in Figure D-1.

3.0 PRE-DEMONSTRATION TEST INPUTS

Prior to the demonstration test, the temperature and pressure timelines for this test will be loaded into the SSFF directory on the Command Computer. Figures D-2 through D-5 contain the timeline definitions.

4.0 DEMONSTRATION TEST INPUTS

1) Automatic processing commands
2) Telemetry log file names
3) Screen selections on the telemetry and graphics computers.

5.0 EXPECTED OUTPUTS

The following outputs will be to the telemetry and graphics computers:

1) Furnace temperature tracking data to the telemetry and graphics computers
2) Furnace temperature stability data to the telemetry and graphics computers
3) Furnace temperature ramp rate data to the telemetry computer
4) Pressure data to the telemetry computer
5) Water temperature data to the telemetry computer
6) Gas and water flow rate data to the telemetry computer
7) Heater data (current, voltage, power) to the telemetry and graphics computers

6.0 DEMONSTRATION TEST PROCEDURE

Table D contains the detailed test procedure for the SSFF SSL Furnace and Transparent Furnace Demonstration Test.

7.0 TEST EVALUATION

The output data will be evaluated against the database timelines. This evaluation includes the data output to the telemetry and graphics screens and the data logged by the telemetry computer during the demonstration test.

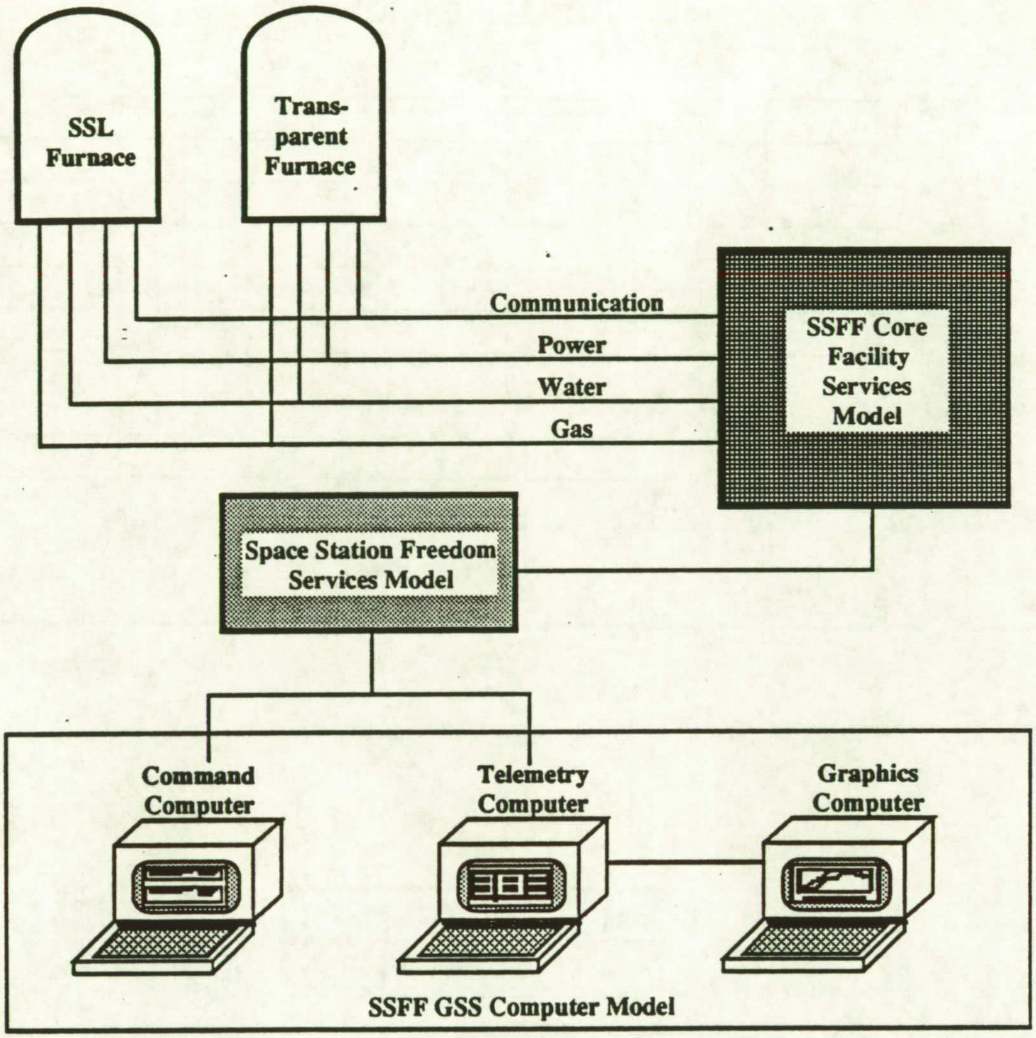
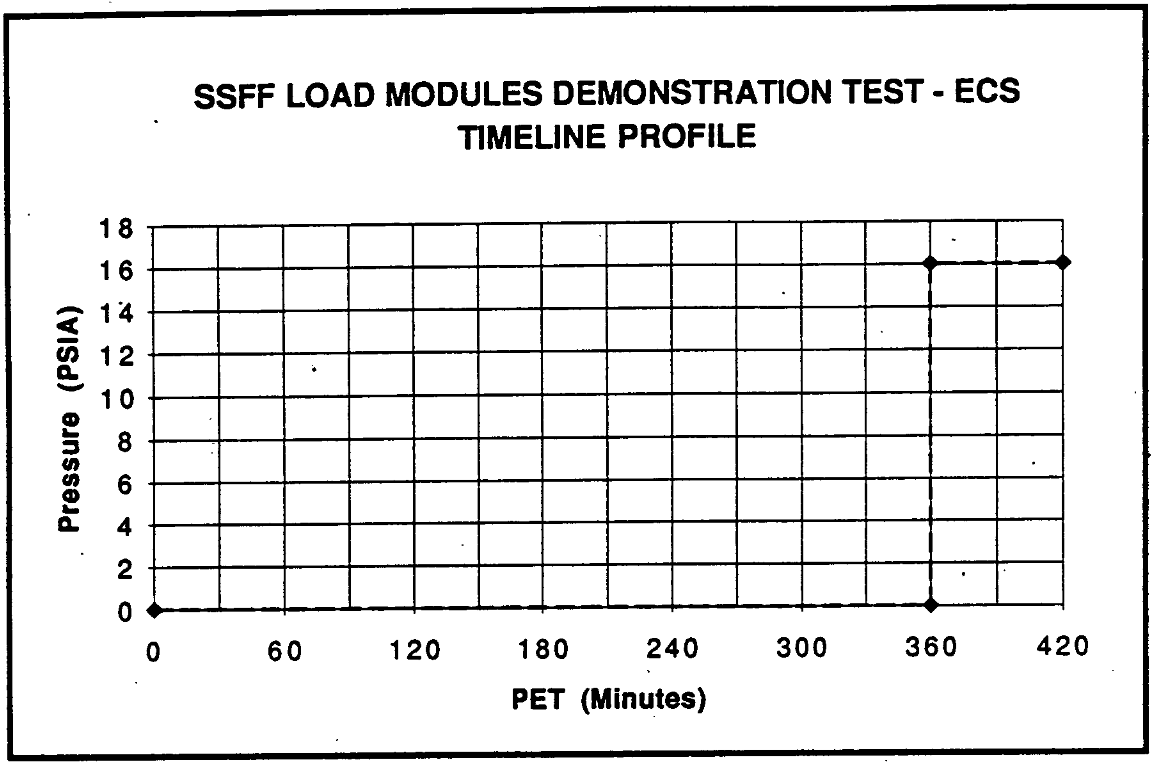


Figure D-1 SSFF SSL Furnace and Transparent Furnace Demonstration Test Configuration



PET Minutes	PSIA
0	0
360	16
420	16

Figure D-2 Environmental Control System Timeline

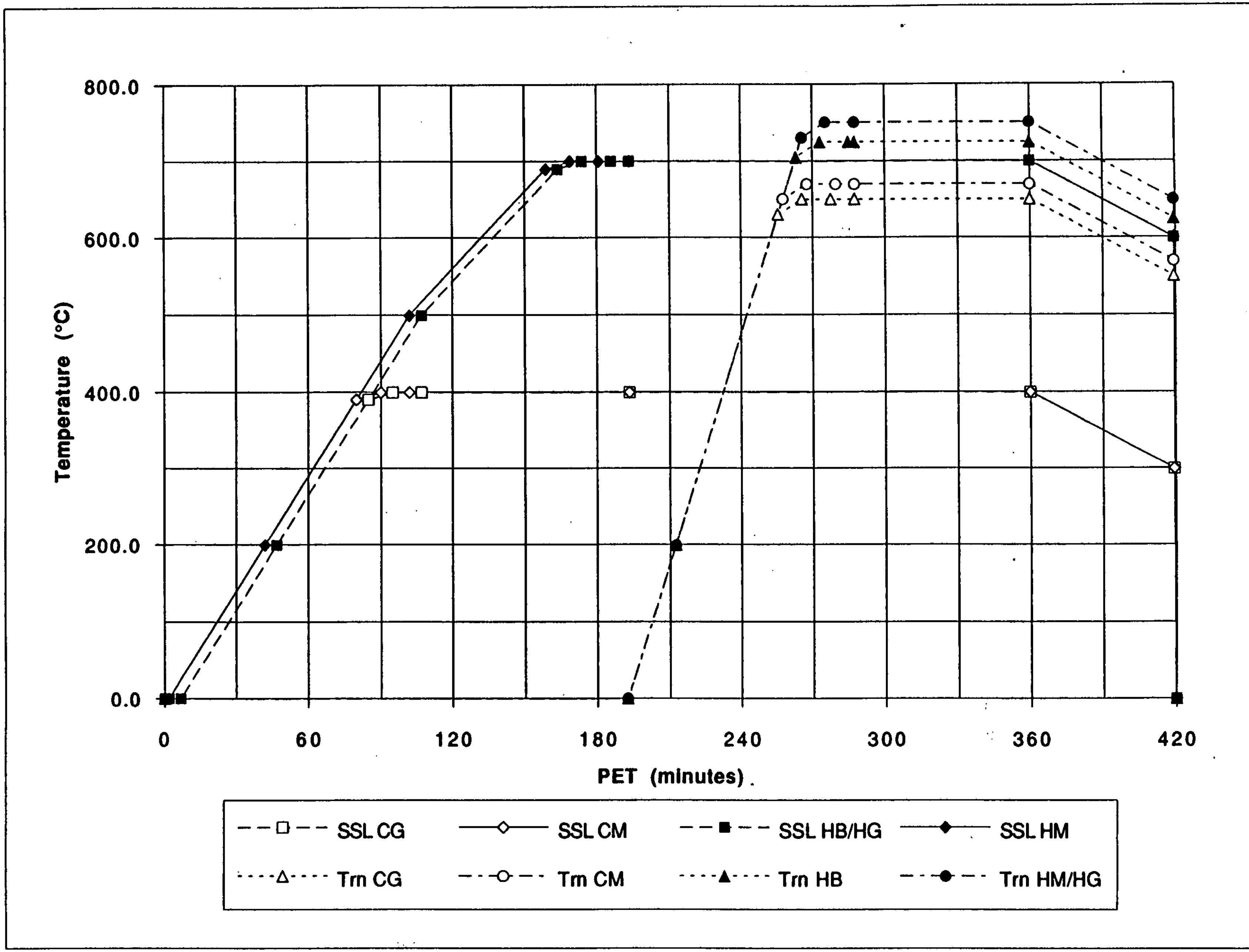
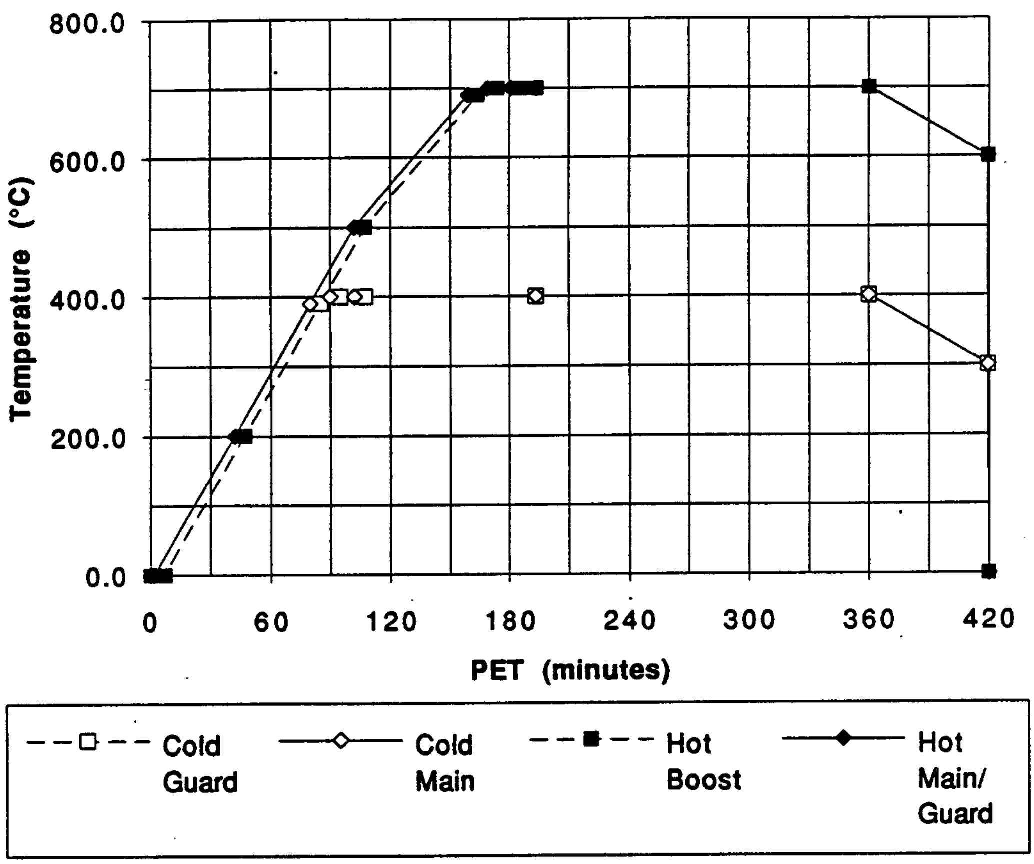
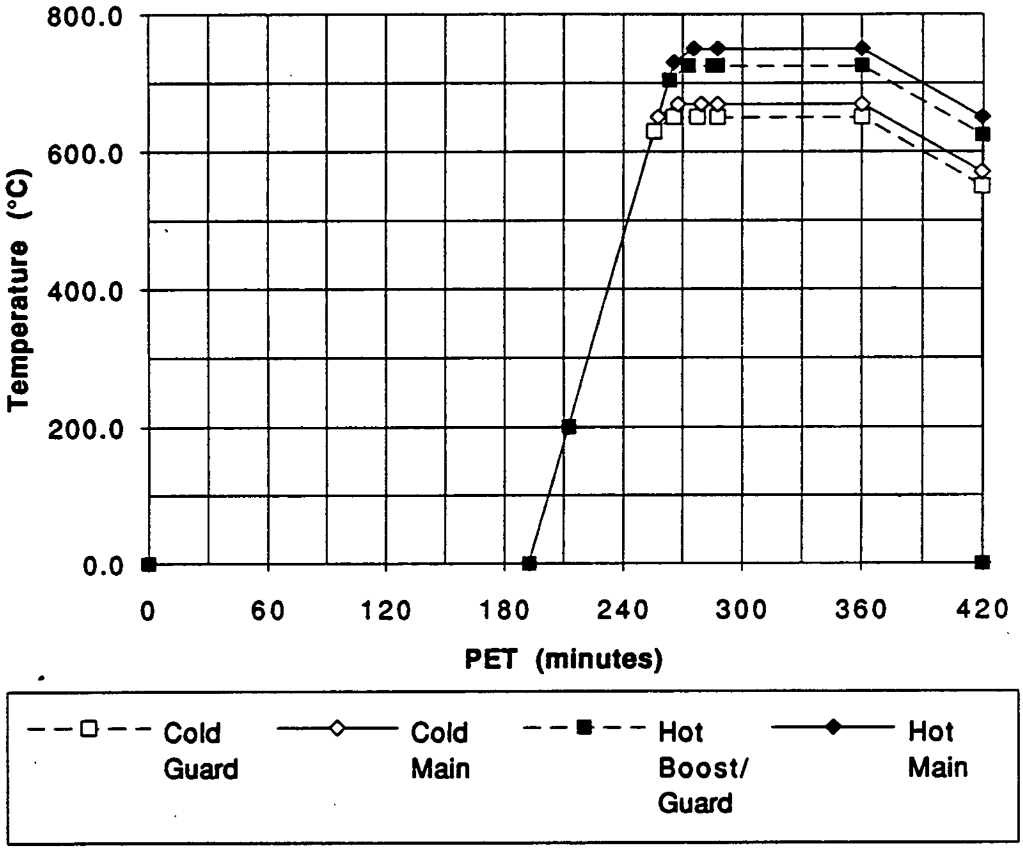


Figure D-3 Furnace Heating System Timeline Profile for SSL Furnace and Transparent Furnace Demonstration Test



Cold Guard		Cold Main		Hot Boost		Hot Main/Guard	
Minutes	°C	Minutes	°C	Minutes	°C	Minutes	°C
0.0	0	0.0	0	0.0	0	0.0	0
2.0	0	2.0	0	2.0	0	20.0	0
7.0	0	42.0	200	7.0	0	42.0	200
47.0	200	80.0	390	47.0	200	102.0	500
85.0	390	90.0	400	107.0	500	159.0	690
95.0	400	102.0	400	164.0	690	169.0	700
107.0	400	193.5	400	174.0	700	181.0	700
193.5	400	360.0	400	186.0	700	193.5	700
360.0	400	419.5	300	193.5	700	360.0	700
419.5	300	420.0	0	360.0	700	419.5	700
420.0	0			419.5	600	420.0	600
				420.0	0		0

Figure D-4 Furnace Heating System Profile and Timeline for SSL Furnace



Cold Guard		Cold Main		Hot Boost/Guard		Hot Main	
Minutes	°C	Minutes	°C	Minutes	°C	Minutes	°C
0.0	0	0.0	0	0.0	0	0.0	0
192.5	0	192.5	0	192.5	0	192.5	0
212.5	200	212.5	200	212.5	200	212.5	200
255.5	630	257.5	650	263.0	705	265.5	730
265.5	650	267.5	670	273.0	725	275.5	750
277.5	650	279.5	670	285.0	725	287.5	750
287.5	650	287.5	670	287.5	725	360.0	750
360.0	650	360.0	670	360.0	725	419.5	650
419.5	550	419.5	570	419.5	625	420.0	0
420	0	420	0	420.0	0		

Figure D-5 Furnace Heating System Profile and Timeline for Transparent Furnace

TABLE D1
SSFF SSL FURNACE AND TRANSPARENT FURNACE DEMONSTRATION TEST PROCEDURE

Step No.	Operator/Equipment Action	Expected Response	Evaluation Criteria	Criteria Met
1	At the Telemetry Computer, enter the following from Screen 6 to initiate logging: <F3>DEMOTR1.LOG<Enter> **NOTE:** Create a new log file at the times indicated by entering: <F5>new log name<F10>	"Logging on." is displayed at the lower right corner.	Exact	______
2	At the Command Computer, enter the following to begin Sample 1 processing for the SSL Furnace: C 1<F10> 1<F10> 1<F10>	At Screen 6 of the Telemetry Computer, observe the F1 VENT valve status change to OPEN and the F1 PRES change to 0.0 PSIA.	Exact; ±1.5 psia	______
3	When FURN1 PET seconds reads 1, at the Command Computer, enter the following to begin Sample 2 processing for the Transparent Furnace: 1<F10> 2<F10> 2<F10> **NOTE:** Create new log files: DEMOTR2.LOG @ **4500** ___ SSL Furnace PET seconds DEMOTR3.LOG @ **9240** ___ SSL Furnace PET seconds DEMOTR4.LOG @ **15000** ___ SSL Furnace PET seconds DEMOTR5.LOG @ **21300** ___ SSL Furnace PET seconds	At the Telemetry Computer: 1. Furn 2 PET begins incrementing.	1. Exact	______
		2. At Screen 9, by **145** PET seconds, SSL Furnace heater zones begin to heat as shown in Figure D-4.	2. Exact	______
		3. By **6420** PET seconds, actual temperatures for the SSL Furnace COLD GUARD and COLD MAIN heater zones correspond to the 400°C set points displayed.	3. Exact	______
		4. By 11610 PET seconds, actual temperatures for the SSL Furnace BOOSTER, HOT MAIN and HOT GUARD heater zones correspond to the 700°C set points displayed and, on screen 11, the heater zones for the Transparent Furnace have begun to heat as shown in Figure D-5.	4. Exact	______
		5. By 17250 Furn 2 PET seconds, the actual temperatures for all Transparent Furnace heater zones correspond to the set points displayed.	5. Exact	______
		6. After 21600 Furn 2 PET seconds, at Screens 9 and 11 of the Telemetry Computer and Screens 16 and 17 of the Graphics Computer, observe the cool down of the SSL and Transparent Furnaces.	6. Exact	______

TABLE D1
SSFF SSL FURNACE AND TRANSPARENT FURNACE DEMONSTRATION TEST PROCEDURE

Step No.	Operator/Equipment Action	Expected Response	Evaluation Criteria	Criteria Met
4	At the Telemetry Computer, observe Screen 1 when Furnace 1 and Furnace 2 PET seconds display **25200.**	System State displays "Manual".	Exact	______
5	At the Telemetry Computer, enter the following to turn of data logging: <F4>	"Logging off." is displayed.	Exact	______

GSE REQUIREMENTS DEFINITION REPORT
FOR
SPACE STATION FURNACE FACILITY

Prepared For

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, AL 35812

Contract No. NAS8-38077

Prepared By

ADVANCED PROGRAMS
SPACE PROGRAMS DIVISION
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HUNTSVILLE, AL 35807

FOREWORD

This report was prepared by Roy Williams of the Material Processing Branch, Advanced Programs, Space Programs Division of Teledyne Brown Engineering under DR-8 in response to Task 5.8 of the NASA contract NAS8-38077for George C. Marshall Space Flight Center. Any questions or comments may be addressed to Mr. Greg Jenkins, Teledyne Brown Engineering SSFF Project Manager.

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1.0 INTRODUCTION

The Space Station Furnace Facility (SSFF) will be designed to accommodate a variety of furnace modules and micro-gravity experiments over a life time of 30 years. During this period, beginning with the initial development and delivery of the first components, there will be almost a continuous flow of activities associated with SSFF. The SSFF development is divided into two major elements, the Furnace Modules and the common systems called the SSFF Core Facility. Ground Support Equipment (GSE) will be required starting with the verification and acceptance testing of these two elements and the eventual integration and test of the complete SSFF facility. In addition there will be operational test flows, handling and shipping, refurbishment processes, system and subsystem upgrades, software development and software verification occurring continuously through out the program. These activities must be supported by special GSE, ground test articles and support facilities. This report, in response to Task 5.8 of SSFF Contract NAS8-38077, provides a general definition of the SSFF GSE required to meet these activities.

2.0 PURPOSE AND SCOPE

The purpose of this report is to define the requirements for GSE needed to support the development, handling, integration and checkout of the SSFF elements, the core rack, experiment racks and furnace modules. The scope of this report includes descriptions of rack handling operations, test/checkout and process flows in addition, to the definition of the GSE required for meeting those activities. Because the maturity of the SSFF design will not support its definition, this report does not address GSE requirements for manufacturing or refurbishment activities. A listing of generic type GSE in groupings are provided in the applicable sections.

For purposes of this report, the term SSFF include both the SSFF core equipment, racks and furnace module. A block diagram of the SSFF three rack configuration is shown in Figure 2.0-1.

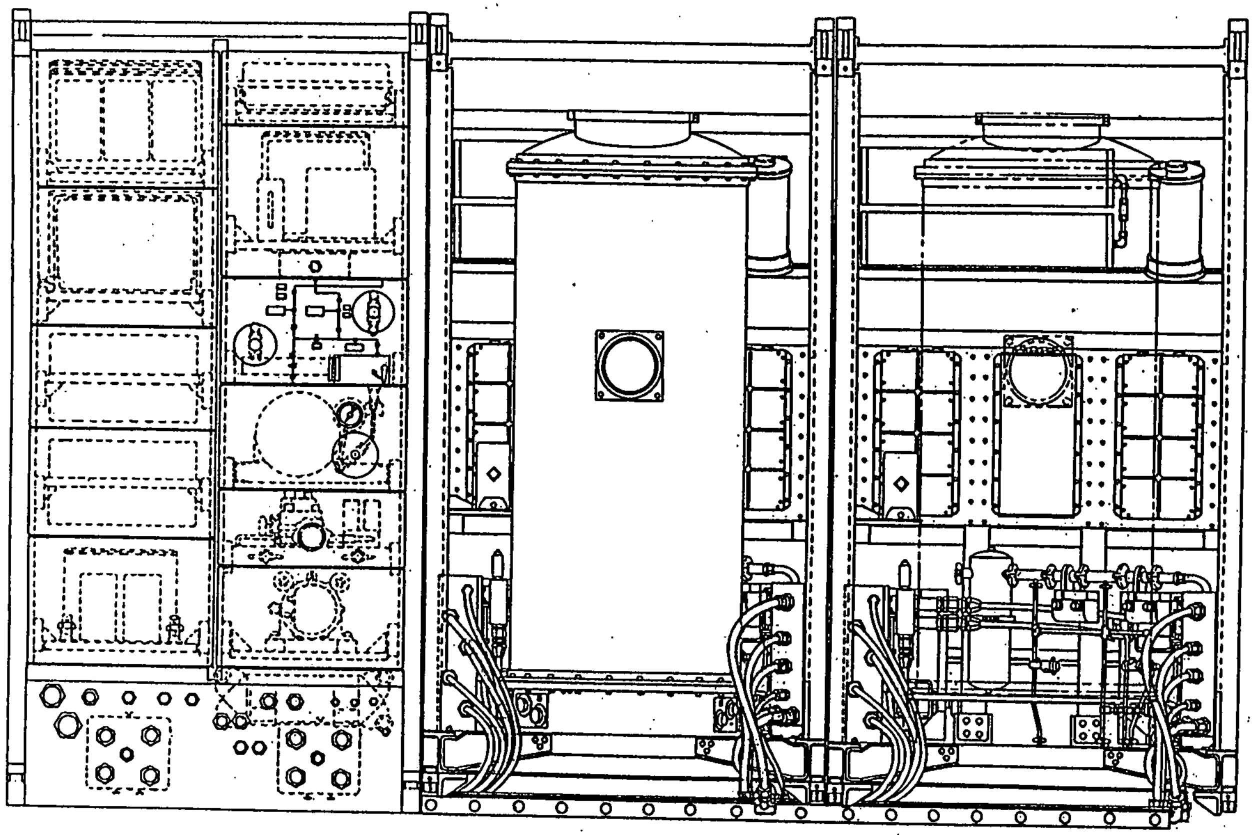

FIGURE 2.0-1 SPACE STATION FURNACE FACILITY (SSFF)

3.0 SSFF DEVELOPMENT AND PRELAUNCH PROCESSING

The requirements for GSE that will be used to support SSFF testing were defined based on the testing activities beginning with interface verification at the different element sites through the prelaunch and post landing processing of the SSFF. The GSE defined to satisfy these test requirements must consist of a host computer system that manages the test hardware/software and executes the testing, provides/controls the necessary resources and has the high fidelity interface simulators of the interfacing SSFF elements and the SSF. To be cost effective, the GSE element test sets should be of a common design and be a subset of the integrated SSFF test set. The GSE test sets defined are described in section 3.2 and are shown in Figures 3.2-1 and 3.2-2. Predicted program schedules indicate ground support equipment will not be available early enough in the program to support the development and interface verification of the initial elements. This will require special GSE and is described in Section 3.1. Qualification and acceptance testing of the SSFF elements, with schedule permitting, will utilize the appropriate test sets as identified in Section 3.2.

3.1 DEVELOPMENT TESTING

During development of the Furnace Module and Core Facility, it will be necessary that the interface of each element be controlled by a program approved Interface Control Document (ICD). In addition to the ICD and in the absence of special GSE to verify the interfaces, there should be a reciprocal exchange of functional and physical interface simulators by the two developers. The simulators would include templates for structural mating, panels, connectors, and functional interfaces that simulate the interfacing article. The Development Test Article (DTA) developed for proof of design by the supplying organization during their development phase could be refurbished and upgraded to satisfy the requirements of an interface simulator.

3.2 SSFF ELEMENT/RACK PROCESSING

This section describes the handling and prelaunch process flows of the SSFF elements and rack flows. The flows are based on the initial launch of the SSFF Core rack and Experiment Rack with Furnace Module-1 (Integrated

Configuration-1 [IC-1]) the launch of Experiment Rack 2 with Furnace Module-2, and the post landing, refurbishment, and reverification of a returned experiment rack and furnace module. Section 3.2.1 through Section 3.2.7 describes the prelaunch and post landing processing of the different elements of the SSFF.

Functional tests of each rack and furnace module are performed and interfaces progressively verified as the processing and build up of the SSFF is performed. Test sets to accommodate these tests and verifications must include both high fidelity physical and functional interface simulators and adaptors, including support equipment to supply resources such as power, and fluids, and a host computer system. The overall GSE test set configuration is shown in Figure 3.2-1 and the major hardware/software elements are listed in Table 1. The individual test sets identified in Figure 3.2-2 (subsets of the overall test set of Figure 3.2-1) are configured from the test set complement listed in Table 1 to accommodate the different SSFF configurations and tests flows shown in Figures 3.2-3, 3.2-4 and 3.2-5. All or portions of the GSE, as identified in Figure 3.2-1, can be at the different process sites or different element development sites as required. The complete set, for example, would be required at the SSFF integration sites to accommodate any SSFF rack, furnace module or combination of configurations.

Test set 2 would be the only set required at the furnace module developer site. Rack processing during prelaunch, as shown in Figure 3.2-3, consists of checkout and integration of the SSFF Core, furnace module, individual outfitted racks, and SSFF as an integrated system. Figure 3.2-4 shows prelaunch processing of the second integrated experiment rack. Figure 3.2-5 shows the return and refurbishment of an integrated experiment rack preparatory to SSFF checkout and reflight. (With the exception of the inclusion of the Furnace Module Figure 3.2-5 could also apply to a core rack that has been returned for refurbishment or upgrading). GSE test set configurations required during the process flows are noted in the process flow figures.

3.2.1 CORE RACK CHECKOUT

Tests, using GSE test set 1, which includes the SSF and two experiment rack interface simulators, will be performed to verify proper operations of the integrated core rack. Testing will include operation and checkout of each subsystem and component tests to operational limit, and the exercising of each

external interface function through the use of SSF and experiment racks adaptors and simulators. Test configuration 1, as shown in Figure 3.2.1-1 will be used to perform this test.

3.2.2 EXPERIMENT RACK CHECKOUT

The experiment rack checkout, using test set configuration 2 shown in Figure 3.2.2-1, will consist of verifying the performance to operational limits of the SSFF distributed subsystems in the experiment rack and their interfaces to the core rack and furnace module.

3.2.3 FURNACE MODULE CHECKOUT

Furnace module tests, using test configuration 3 shown in Figure 3.2.3-1, will be used to verify the performance to operational limits with the exception that heater modules will only be tested to the extent that they prove operable. The furnace module interface to the experiment rack will be verified through the functional performance tests and the physical connects of the experiment rack simulator.

3.2.4 INTEGRATED EXPERIMENT RACK CHECKOUT

Following integration of the furnace module into the experiment rack the rack performance and interfaces will be verified using a core rack simulator and test set. Tests will be limited to only those required to verify furnace module to experiment rack interfaces. The tests set configuration is shown in Figure 3.2.4-1

3.2.5 SSFF FACILITY CHECKOUT

Following checkout of the individual racks, an overall SSFF integrated systems test is performed using test set configuration 5. The test configuration is shown in Figure 3.2.5-1. Tests will be limited to verify rack-to-rack interfaces and to the simulated interfaces of a second experiment rack and SSF.

3.2.6 KSC VERIFICATION

Physical integration at KSC will be limited to receiving/inspection of the SSFF hardware complement and reverification of the physical and functional

capabilities and all test sets to accommodate any SSFF rack, furnace module or combination thereof.

3.2.7 POST LANDING

Post landing activities consists of removing the SSFF equipment and experiment samples from the returning Mini Pressurized Logistics Module (MPLM), return of the samples to the Payload Investigators, removal of the furnace module from the experiment rack and return to the PED, and refurbishment of the experiment rack. These activities are shown in Figure 3.2-5.

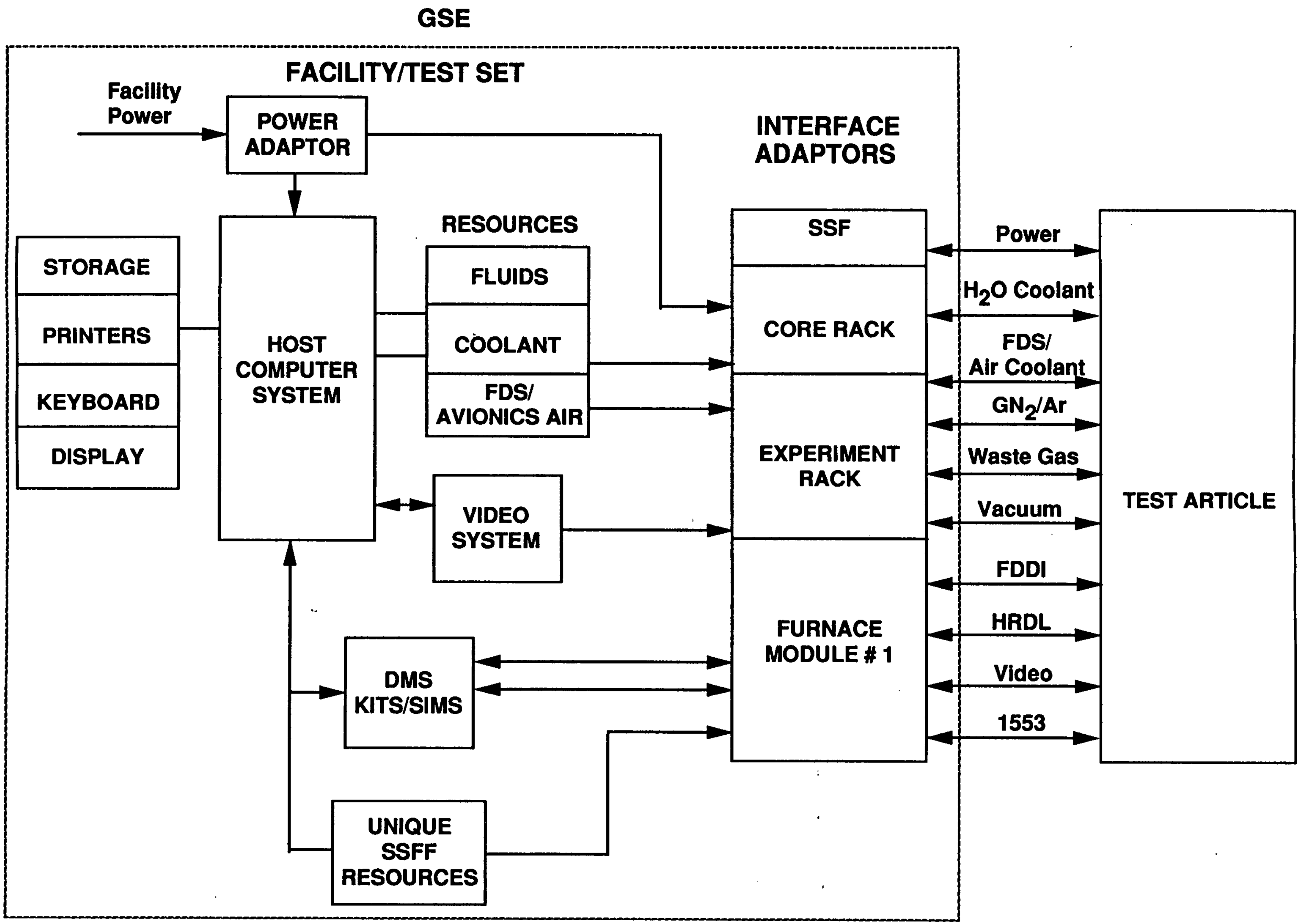

FIGURE 3.2-1 SSFF GSE TEST SET CONFIGURATION

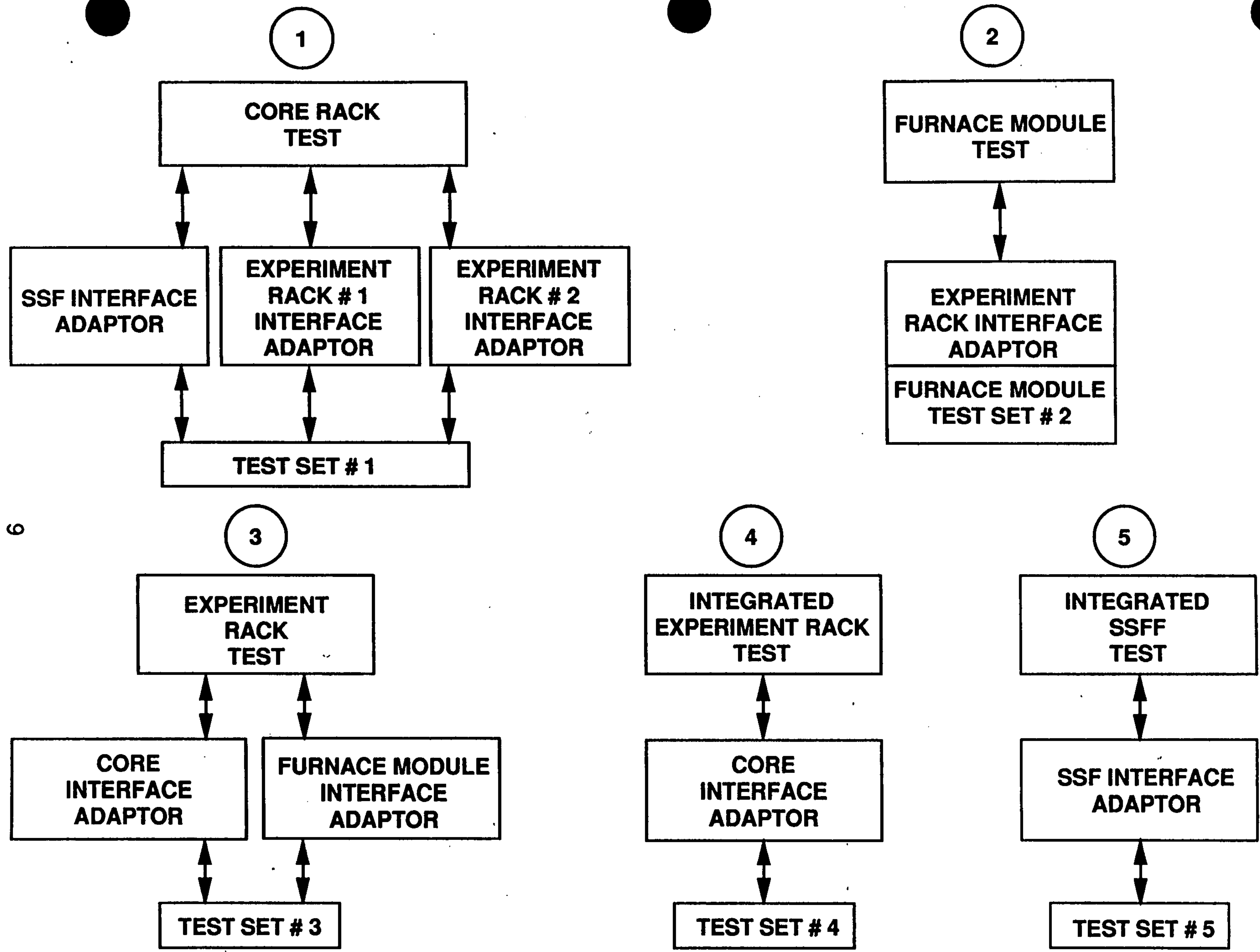

FIGURE 3.2-2 TEST SET CONFIGURATIONS

TABLE 1. SSFF TEST SET HARDWARE/SOFTWARE

1. Host Computer System

   - Test Control Software
   - Test Data Diagnostics Software
   - Keyboard & Monitor
   - Data Storage Device
   - Printer

2. Simulator, SSF to SSFF Core

   - Interface Panels/Adaptors
   - Facility Power Converter
   - Resource Servicers
     Coolants
     Fluids
   - DMS Functional Interface Simulators

3. Simulator, SSFF Core To Experiment Rack

   - Interface Panels/Adaptors
   - Facility Power Converter
   - Resource Servicers
     Coolants
     Fluids
   - DMS Functional Interface Simulators

4. Simulator, Experiment Rack to SSFF Core

   - Interface Panels/Adaptors
   - Functional Interface Simulators
   - Resource Loads
     Power
     Coolants
     Fluids
     Data

5. Simulator, Experiment Rack to Furnace Module

   - Interface Panels/Adaptors
   - Facility Power Converter
   - Resource servicers
     Coolants
     Fluids
   - Functional Interface Simulators
   - Test Controls and Monitoring

TABLE 1. SSFF TEST SET HARDWARE/SOFTWARE (CON'T)

6. Simulator, Furnace Module to Experiment Rack

   - Interface Panels/Adaptors
   - Functional Interface Simulators
   - Resource Loads
     Power
     Coolants
     Fluids
     Data

7. Subsytem Test Sets (Hardware/Software)

   - TCS
   - EPS
   - GDS
   - DMS
   - Video

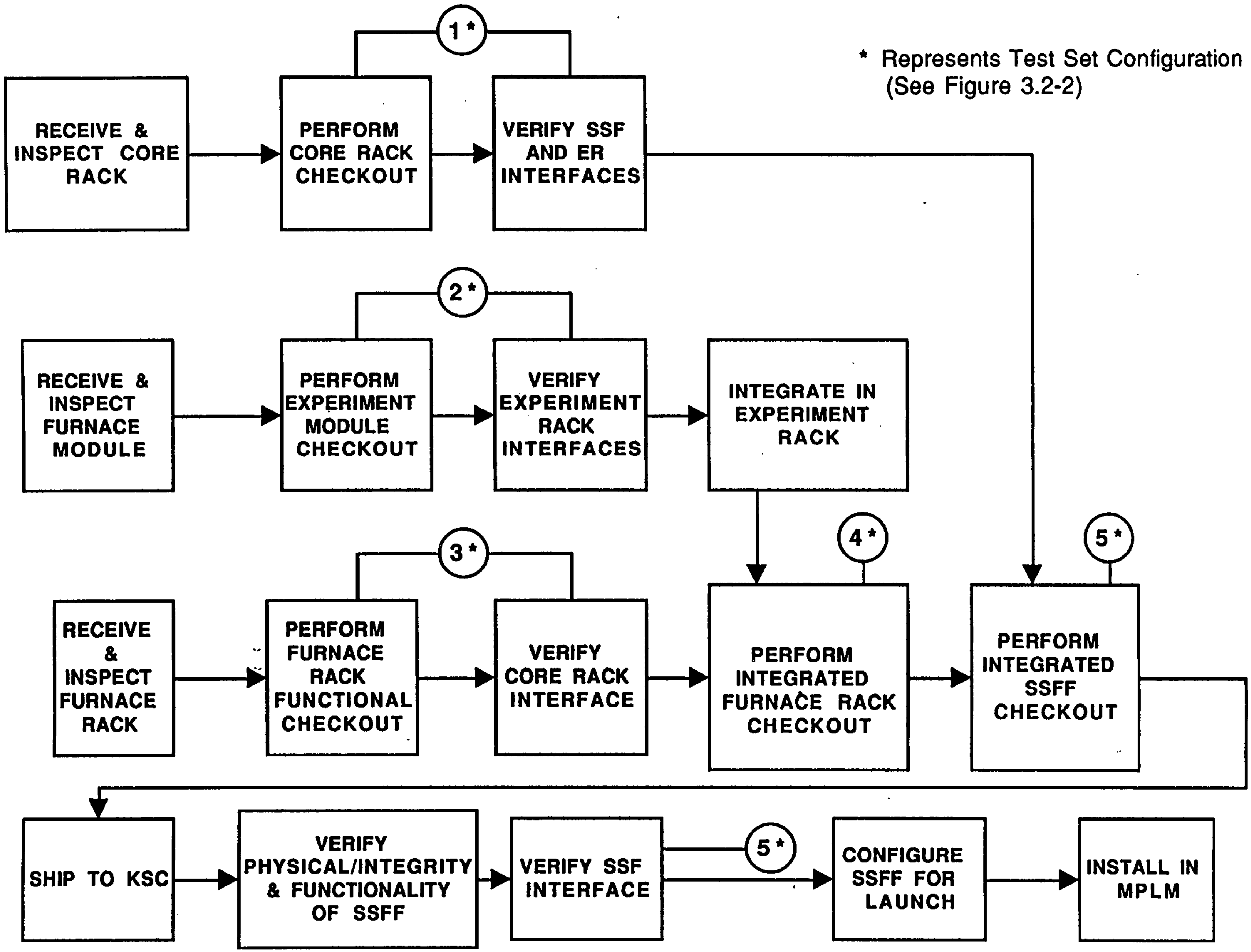

FIGURE 3.2-3 PRELAUNCH PROCESSING FLOW

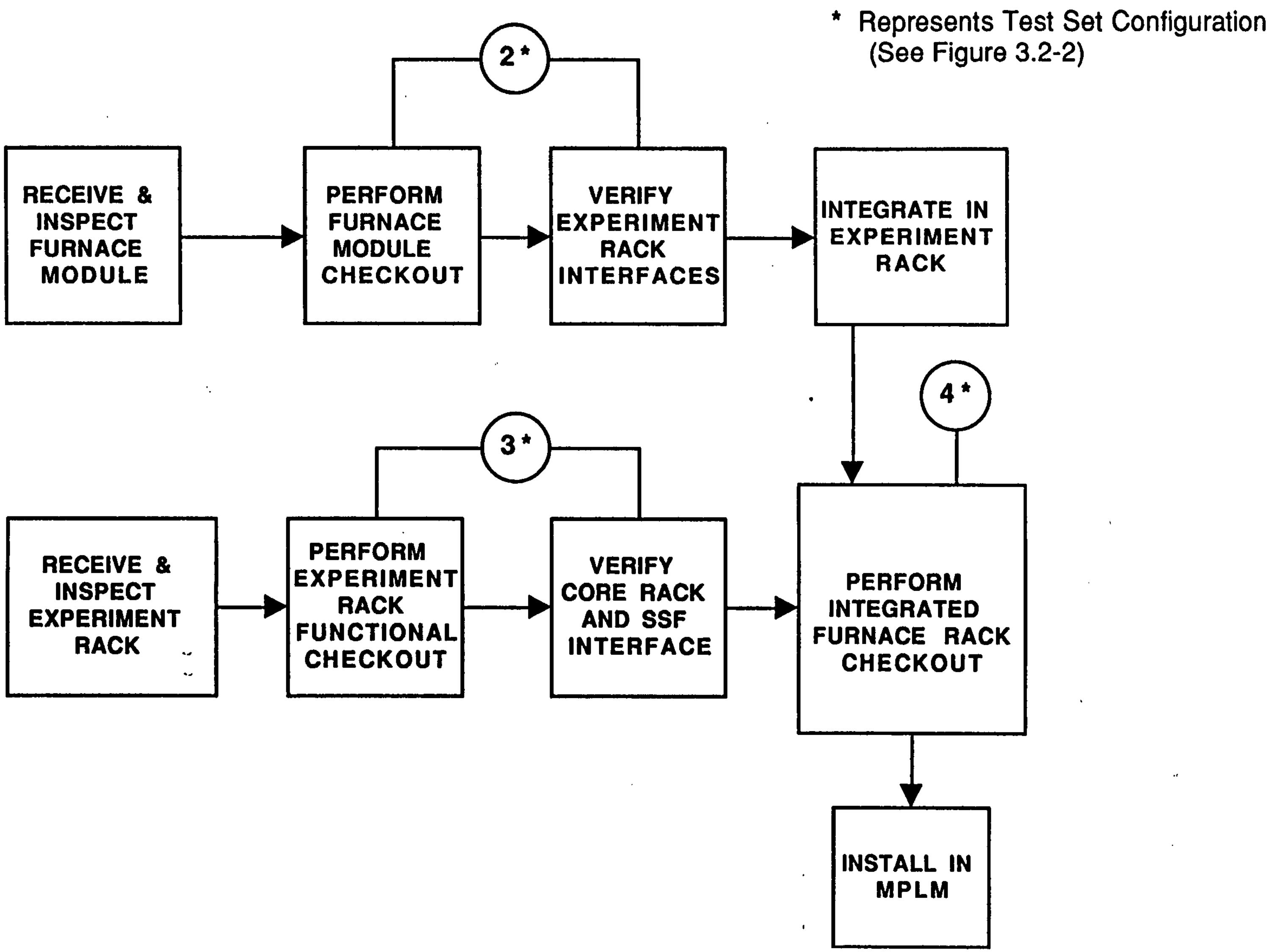

FIGURE 3.2-4 EXPERIMENT RACK FLOW

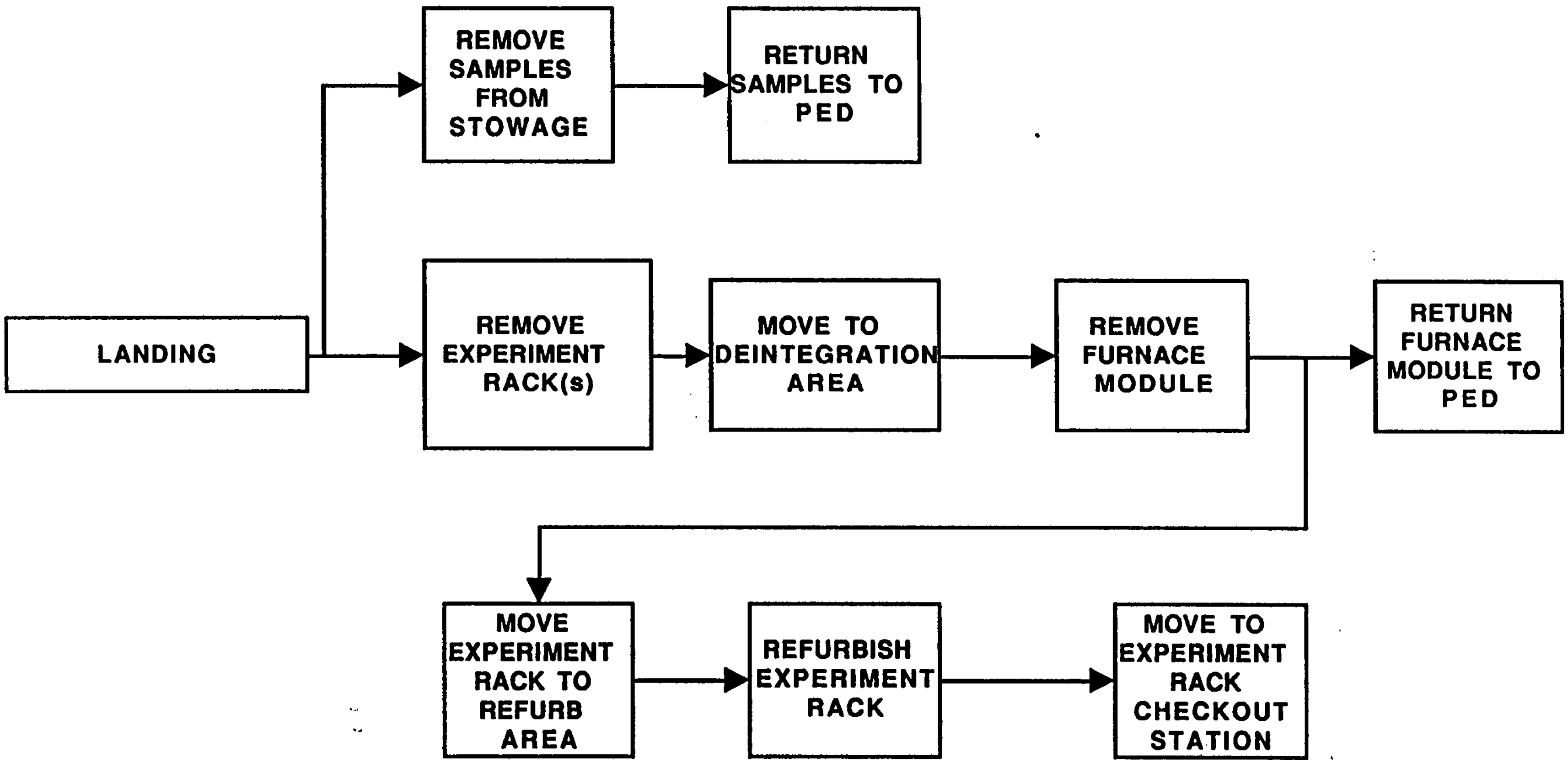

FIGURE 3.2-5 POST LANDING PROCESSING

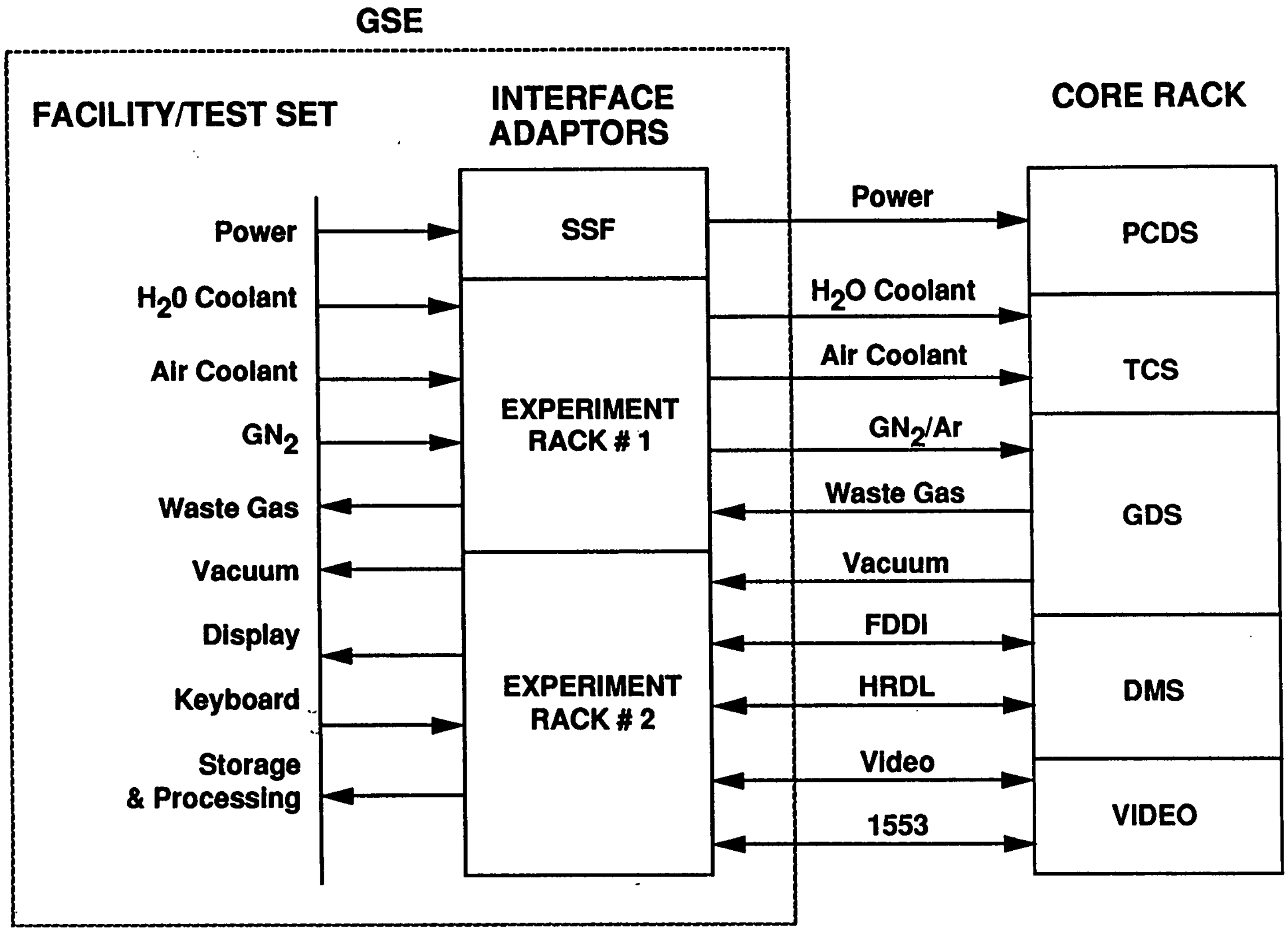

FIGURE 3.2.1-1 CORE RACK CHECKOUT CONFIGURATION

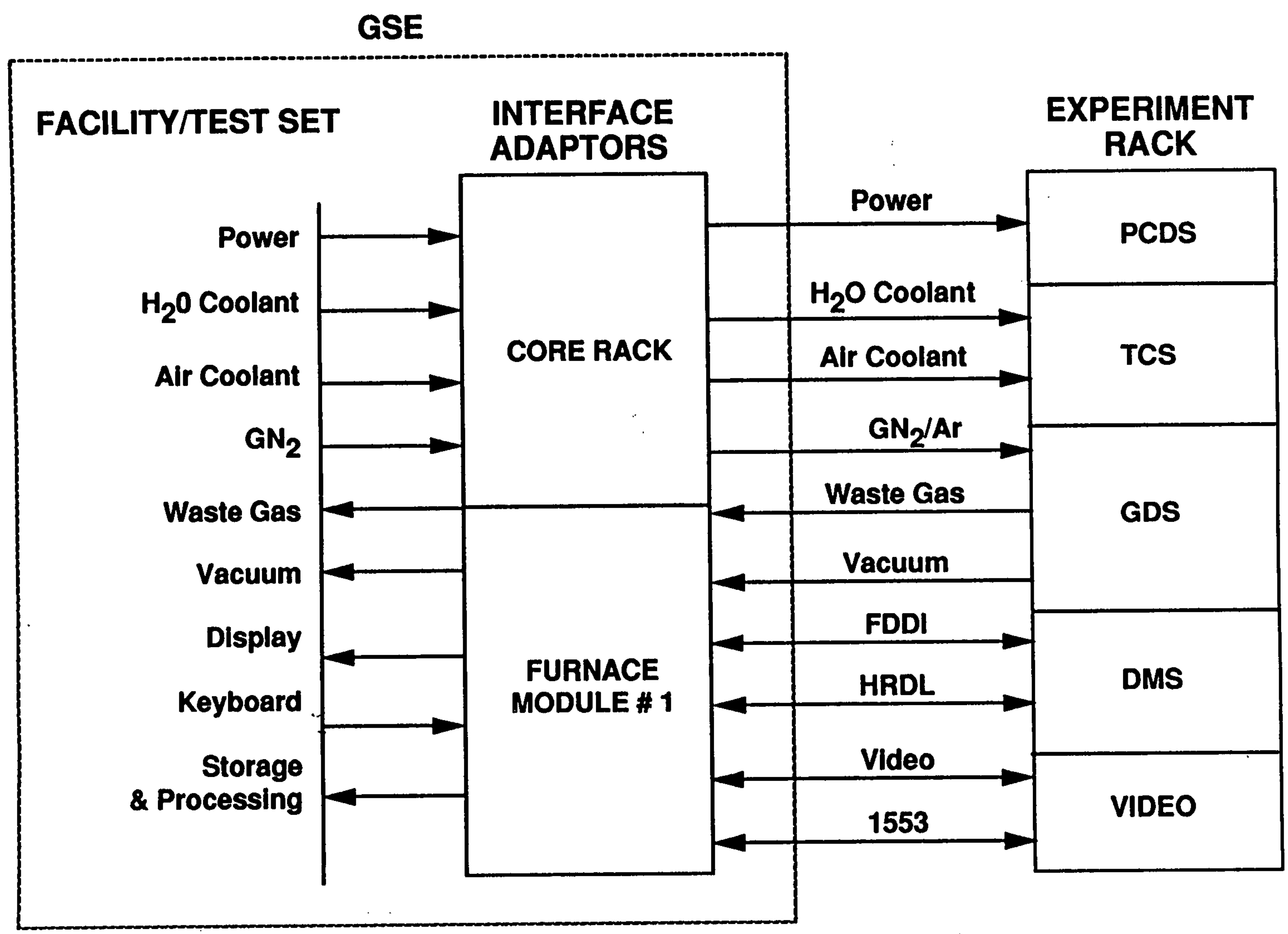

FIGURE 3.2.2-1 EXPERIMENT RACK CHECKOUT CONFIGURATION

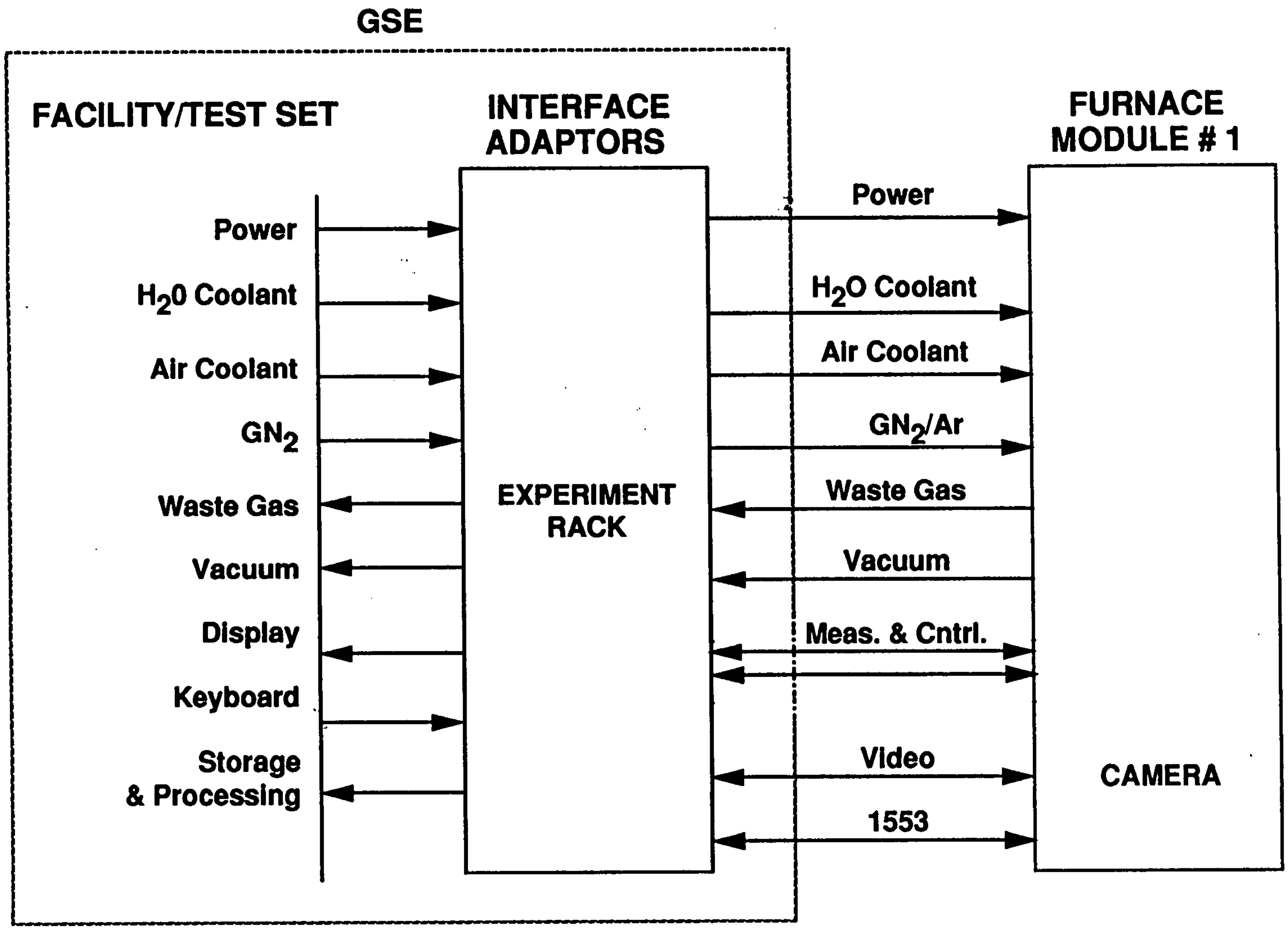

FIGURE 3.2.3-1 FURNACE MODULE # 1 CHECKOUT CONFIGURATION

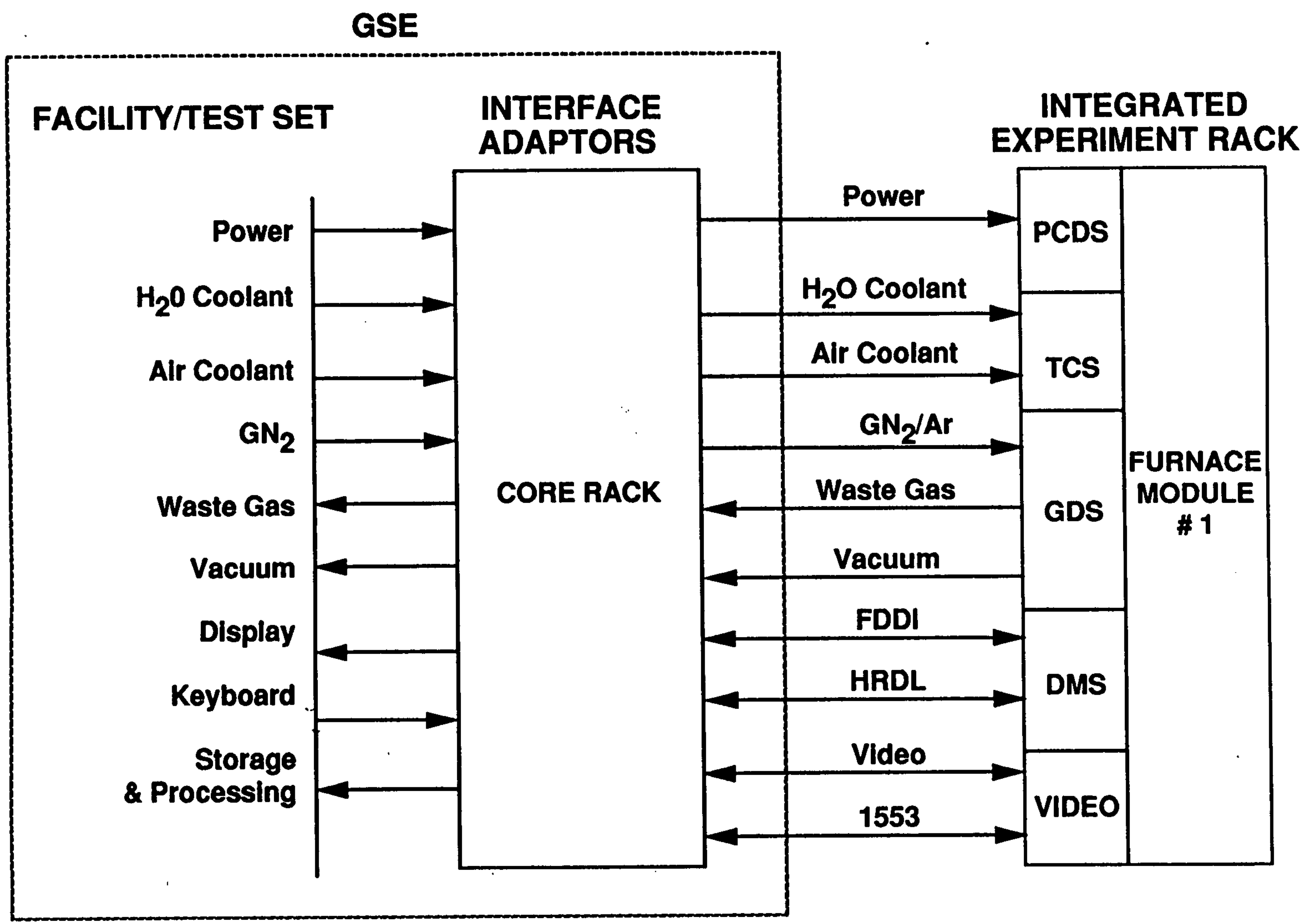

FIGURE 3.2.4-1 INTEGRATED EXPERIMENT RACK

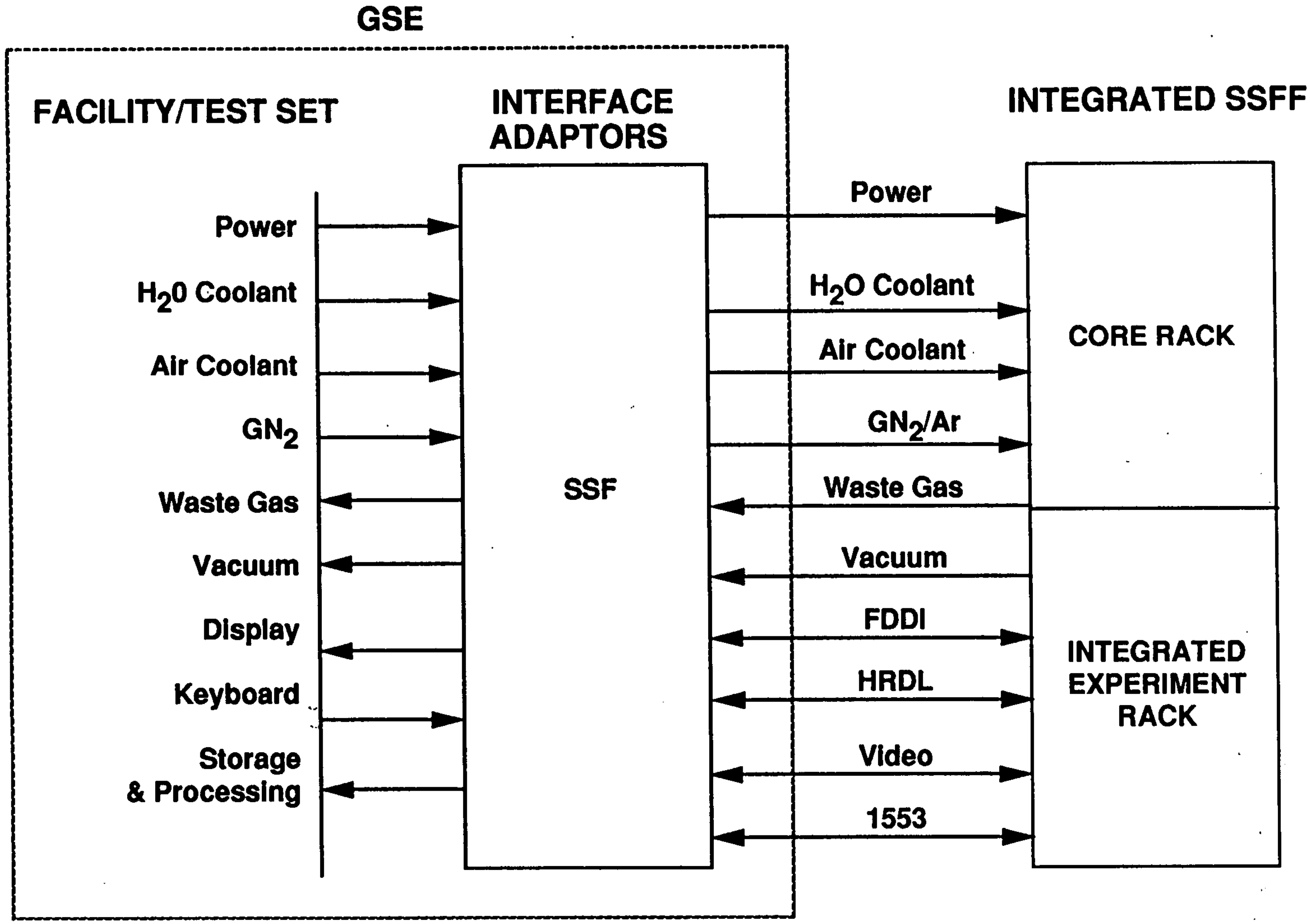

FIGURE 3.2.5-1 SSFF INTEGRATED SYSTEM TEST

4.0 RACK HANDLING REQUIREMENTS

Rack handling and support equipment will be required for rack structural interfacing, general handling, rack protection, movement from work station to work station, rack rotation to accommodate access and integration of rack hardware, and lifting and shipping of racks. The hardware types which meets these requirements are listed in Table 2 and was derived from the rack integration flows and descriptions of handling devices developed by TBE for the SSFF WP-01.

TABLE 2. RACK HANDLING EQUIPMENT

1. Drill Jig for standard equipment used to drill holes and etc. to accommodate SSF standard equipment such as for the fire detection and avionics air.

2. Drill Jig for unique equipment used to drill holes and etc. to accommodate the unique hardware such as the SSFF hardware complement.

3. Rack handling adapter (G1072)*, a rigid device that mounts to the rack and provides an interface for other rack handling devices such as the rack rotation stand to attach to.

4. Shipping Container (G1094) provides physical and environmental protection for the racks during shipment.

5. Rack Rotation Stand (G-1171), a fixture that interfaces to the rack handling device and performs the movement, rotation and handling of the rack during installation of equipment.

6. Rack Handling Sling (G-1070), a device used for handling racks during installation and removal from shipping containers and the rack integration stand .

7. Connectors Savers Connector adapters which interface and provide protection to the flight interfaces during testing.

5.0 SSFF HARDWARE/SOFTWARE FACILITY REQUIREMENTS

A strong ground base will be required by the SSFF program to provide support for on-orbit diagnostics, a test base for SSFF hardware, support for software modifications and a platform and software environment for development and test of new programs. The need for ground test bed to support diagnostics and workarounds will be especially critical in the SSFF because of limited crew time.

A base to support these activities will require two facilities/test beds. One test bed will be a SSFF Ground Control Experiment Laboratory (GCEL) providing support for pre-mission timeline development and calibration in addition to general experiment support. The GCEL should be a high fidelity replica of the full SSFF configuration with an appropriate host computer system to provide not only support for the experimenter but on-orbit diagnostics and a test base for verification of hardware upgrades. The SSFF units used for qualification could be the basic hardware complement for the GCEL configuration.

A SSFF facility test bed functionally identical to the flight will be required to provide the capability for software development, verification and validation and hardware prototype tests. This facility should consist of hardware, software, and software simulators that can provide a high fidelity functional equivalent of the onboard SSFF but has the flexibility to accommodate reconfiguration and SSFF hardware and software modifications. The facility, in addition to the SSFF hardware and simulations, will also require host computer system for overall executive control and data base management.

APPENDIX A - ACRONYM LIST

ACRONYM	MEANING
DTA	Development Test Article
GCEL	Ground Control Experiment Laboratory
GSE	Ground Support Equipment
IC-1	Integrated Configuration 1
IC-2	Integrated Configuration 2
ICD	Interface Control Document
KSC	Kennedy Space Center
MPLM	Mini Pressurized Logistics Module
PED	Payload Experiment Developer
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
WP-01	Work Package-01